Dardenne Creek Watershed Study

A Comprehensive Hydraulic Study of Dardenne Creek and its Tributaries

(Dardenne Creek near Highway N and Eagle Hill Lane, April 2006)

Performed By:

The U.S. Army Corps of Engineers, St. Louis District, Hydraulics Branch

John D. Boeckmann, P.E. – Lead Hydraulic Engineer

For:

The Great Rivers Greenway District – Primary Project Sponsor

The cities of Cottleville, Dardenne Prairie, O'Fallon, St. Charles, and St. Peters, and St. Charles County – Additional Local Sponsors

Final Report Date:

January 10th 2007

TABLE OF CONTENTS

1. Introduction

The Dardenne Creek Watershed Study is the first of its kind in St. Charles County, Missouri. Although Dardenne Creek and many of its tributary streams have been studied individually with detailed hydrologic methods, no comprehensive watershed study has been undertaken for a major St. Charles County stream. A comprehensive study involves a regional approach, and incorporates all major tributaries into the study effort.

The St. Charles County Flood Insurance Study (FIS) represented the most recent detailed hydraulic analysis of the streams in the Dardenne Creek watershed. However, at the time of this report, the majority of the hydraulic models from the FIS are between 10 and 30 years old. Due to changing watershed conditions and rapid development throughout the county, local authorities were in need of an updated version of the hydraulic models with the most technically advanced methods. Since the individual studies were completed at different times, and by different engineering companies and agencies, the methods of analysis used were widely varied. A single study covering the entire watershed adds an element of consistency to the study data and results.

Dardenne Creek and its tributaries drain almost 30% of the area of St. Charles County. Many of the largest and quickest growing cities in the county contribute runoff to Dardenne Creek. Therefore, with more people moving into the area every year, there is a potential increase in the number of homes located within and near the floodplain of Dardenne Creek and its tributaries. Also, the recent increase in development has the potential to worsen flooding conditions elsewhere in the watershed. The comprehensive study approach is the most appropriate method of representing the cumulative effects resulting from all of these changes.

Another important factor is the effort being made by the Great Rivers Greenway District (GRG) to promote the use of greenways near major waterways throughout the St. Louis metropolitan region. Greenways are created to maintain open space near creek channels, and to utilize that area for recreation, flood control, and/or ecosystem restoration purposes. As the main sponsor of the watershed study, GRG will use the watershed model to help execute their greenway plan with sound engineering methods, with respect to the flooding conditions near Dardenne Creek and its tributaries. GRG kicked off the Dardenne Greenway Master Plan in the summer of 2006.

Based on the changing conditions in St. Charles County, and the fact that the previous hydraulic models are out of date, this new hydraulic study of the watershed represents a significant and necessary improvement. This report covers the study methods and findings for this important comprehensive study of the Dardenne Creek watershed. Please note that a list of abbreviations and definition of terms used in the report can be found in **Appendix D4**.

2. Background Information

For almost a decade, local authorities in St. Charles County have worked with various Federal and Missouri State agencies to create an updated flood model for Dardenne Creek and its tributaries. Beginning with a research grant provided by the Environmental Protection Agency (EPA) in 1997, the Missouri Department of Natural Resources has been involved with city and county representatives in St. Charles County, in an effort to better understand the Dardenne Creek watershed.

Working with other interested organizations such as the Greenway Network, local representatives formed the **Dardenne Watershed Alliance** in 1999. This group began the process of determining the best use for the EPA grant money and developing a plan for a system of trails and parks near Dardenne Creek. In an effort to gain more information about the frequency and magnitude of flooding on the creek, in late 1999 the Watershed Alliance paid for the installation of two river gages by the United States Geological Survey (USGS). The gages, one at Highway K in O'Fallon, and one in Old Town St. Peters, measured the hourly streamflow discharge and stage level of Dardenne Creek. The information from the gages would be kept in a data base to be used for calibration of hydrologic and hydraulic models produced in the future.

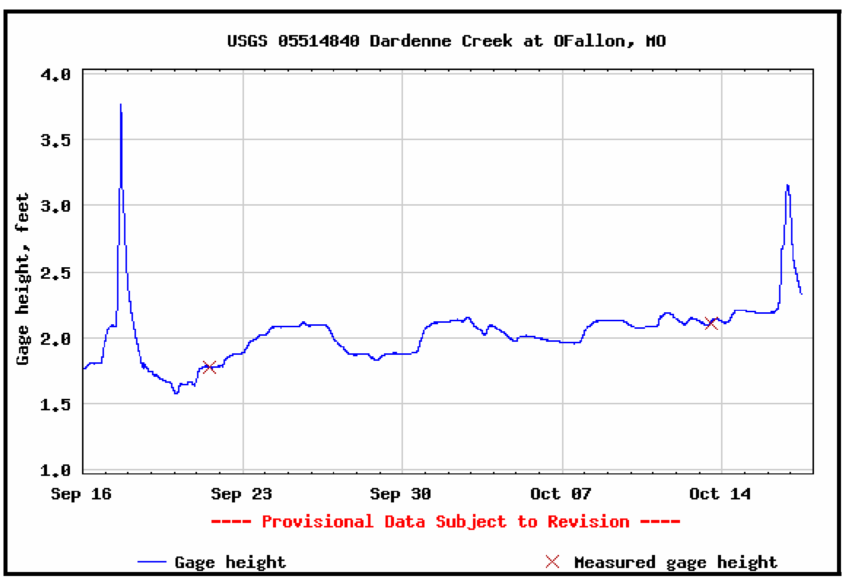

Figure 2.1 – Sample Graph from USGS Stream gage in O'Fallon

In late 2001, the Dardenne Watershed Alliance produced the Dardenne Creek Greenway Conceptual Plan. The goal of the plan was to conserve the Dardenne Creek corridor through improvements to water quality, storm water management, park management, and a system of trails near the creek. This was an important step in the history of Dardenne Creek, as it represented a highly focused approach, involving all of the local city and county governments. The group continued gathering information about the watershed, in hopes of finding a funding source for a more substantial study of the entire watershed area, to be followed by execution of the Greenway plan.

In the following years, the Watershed Alliance began discussions with the **U.S. Army Corps of Engineers**, in an attempt to develop a watershed study project that would utilize the experience that the Corps has in Hydraulic Analysis. The original incarnation of the study was to take place from the Corps' Fiscal Years 2003 to 2004, or from October, 2002 to September, 2004. The Corps would perform an extensive data gathering effort, as well as detailed hydrologic and hydraulic analyses, for an estimated cost of $600,000. The original scope of work for the study is included in this report as **Appendix D1**. All that remained was to find a Federal Project Authority to help fund the study with the local sponsorship.

The Planning Assistance to States (PAS) program was found to be a good fit for the study, because of the comprehensive nature of the study, and its resulting usefulness to the quickly growing St. Charles County. The PAS program is a type of project authorization used by the Federal Government to enter into cost-sharing agreements for water resource projects that benefit a large state or county community. Typically, a local sponsor covers half of the cost, and the Federal government funds the other half. The Dardenne Watershed Alliance brought the **Great Rivers Greenway District** (formerly the Metropolitan Parks and Recreation District) in as the primary project sponsor, and the Corps agreed to cover the remaining half of the project cost.

The Federal funding for the Dardenne Creek Watershed Study project was finally put into place in Spring of 2004. The delay in the availability of funding resulted in a modified time schedule and scope of work, spreading the study over three Fiscal years, 2004-2006. The final modifications to the scope of work are discussed in **Section 4** of this report. The Great Rivers Greenway (GRG) provided the local portion of funding up front, which was $100,000 each Fiscal Year. In another cost sharing agreement with the local authorities, the cities of Cottleville, Dardenne Prairie, O'Fallon, St. Charles, and St. Peters, and St. Charles County, would provide a total of $50,000 each year.

After the funding for the project was in place, the study efforts began in earnest in May of 2004. Surveys and mapping contracts were the first priority, and other data collection efforts and a helicopter survey of the creek got the study underway. The objectives and results of this important study follow here.

3. Study Objectives

The purpose of this project was to analyze the likelihood of flooding for Dardenne Creek, as well as all of its tributaries greater than one square mile in drainage area. The following flood frequencies were analyzed for the base condition in the watershed: The 2, 5, 10, 15, 25, 50, 100, and 500-year storms, with a 48-hour duration. The forecasted conditions were also analyzed, to anticipate the frequency and magnitude of flooding based on the planned development of the watershed in the near future. Due to the various forecasting methods for each city and county office, a single date in the future that represents the forecasted condition could not be chosen.

The analysis of the entire system of tributaries represents a major improvement over previous hydraulic models of the streams. Instead of simply studying the individual creeks, this comprehensive, basin-wide approach provides a better understanding of the streamflow in the Dardenne Creek watershed as an interconnected system.

Another key improvement for this study over the original Flood Insurance Study was the use of up to date GIS data to develop the watershed models. Using recent aerial photography, a terrain model was produced which would be a much better representation of the drainage in the Dardenne Creek watershed than USGS topographic maps. Soil and land use maps in GIS format were also used to estimate hydrologic parameters.

The finished product from this modeling effort can be used as a tool to analyze any number of potential projects affecting the watershed. Stream stabilization, flood damage reduction, ecosystem restoration, and recreation are all possible applications that could make use of the hydraulic models. As the primary project sponsor, Great Rivers Greenway will be able to use the watershed models to analyze the effects of their planned trail system on the stream dynamics. Ultimately, the watershed models will be in the public domain, and may be used for any suitable application, at the discretion of local authorities and the GRG.

4. Final Approved Scope of Work

The original work plan for the Dardenne Creek Watershed Study was documented in a report that is included in **Appendix D1**. The report was called the "Scope of Service for the Dardenne Creek Stormwater Management Plan." The work plan was broken down into ten tasks, each of which represented a particular type of data gathering or watershed analysis.

Throughout the life of the Dardenne Creek Watershed Study, meetings were held that involved the local project sponsors and other interested stakeholders. These meetings were arranged in order to allow the sponsors an opportunity to steer the efforts of the study to better suit their needs. Therefore, some changes were made to the original scope of work, with the approval of the project sponsors. In the event that a particular sponsor's representative was unable to attend a meeting where such a decision was made, the meeting notes were provided so that each sponsor had a chance to comment on the decision before it was finalized.

This section of the report will list each task from the original scope of work and give a brief description of the final work effort required for the task. Any significant changes from the original scope are noted here.

Task 1 – Obtain and Load Mapping

The primary focus of this task was obtaining digital orthophotos (aerials) and developing a 3D terrain model. The FEMA floodplain boundaries were also to be obtained in GIS format. A private contractor completed the mapping requirements, as originally planned, with no modifications to the original scope of work.

Task 2 – Collect and Review Data

Additional data required for the study included bridge and culvert drawings, previous hydraulic models, rainfall and streamflow data, land use and soil maps, and other GIS data. The process of collecting data was originally planned to take place only early on in the study timeline. However, given the large scope of the project, the data collection ended up being an ongoing process that continued until the project was completed. An extra feature that was added to the project was the development of the Dardenne Creek Watershed Study website. Gathering and sorting massive amounts of data was made easier through the use of the Internet, and it seemed logical to make the data available to any interested parties throughout the life of the project. The Corps of Engineers produced and maintained the website, which is located at this location: http://www.mvs.usace.army.mil/DardenneCreek/.

Task 3 – Photograph and Record Watershed Characteristics

The Dardenne Creek watershed was to be photographed extensively during site visits and the mainstem of Dardenne Creek was to be videotaped during a helicopter flyover of the creek. All bridge and culvert crossings were to be inspected, photographed, and measured, if necessary. This task also required additional work in the latter stages of the project, due to the ever-increasing numbers of bridge and culvert crossings. Another significant change to this task was the addition of a second helicopter survey. Due to the initial delay in funding the project, the first helicopter flight took place in June of 2004, when the leaves on the trees made it difficult to see every detail of the creek. Therefore, another trip was taken in March of 2005, when the view of the creek was much clearer. Both video flyovers were geo-referenced and made available to project sponsors.

Task 4 – Develop Hydrologic Model of Dardenne Creek

HEC-HMS, or the Hydrologic Modeling System, is the computer software package that was utilized for the hydrologic model of the entire Dardenne Watershed. HMS was developed by the Hydrologic Engineering Center (HEC), a research center for the U.S. Army Corps of Engineers. Peak flow values were determined for various storm frequencies throughout the Dardenne drainage basin. This task involved some preparatory work that was completed with ArcView GIS package offered by ESRI. The topography of the area was analyzed along with soil and land use data to determine the appropriate hydrologic parameters for the computer modeling. The project work on this task proceeded with no alterations to the original scope of work.

Task 5 – Develop Hydraulic Model of Dardenne Creek Streams

The hydraulic model chosen for the study was the River Analysis System, or HEC-RAS program, which was also developed by HEC. The initial plan was to build a new geometric model of Dardenne Creek and its tributaries with HEC-RAS, directly using the original HEC-2 models that were collected during **Task 2**. However, it was determined that the best use of the available technology was to create a new hydraulic model from scratch with the GeoRAS extension of ArcView GIS. This program allows the user to cut cross sections from detailed terrain mapping to create the stream geometry. The previous hydraulic models were used to fill in the channel sections for streams that were not surveyed completely. A provision in the original scope allowed for the addition of tributaries to Dardenne Creek that were previously unstudied, and four of them were added in this manner (Old Dardenne, Oday Branch, and two unnamed tributaries that were named Tributary 17 and Tributary 19). All other work on this task proceeded as planned.

Task 6 – Perform Field Surveys

The cross sections for the HEC-RAS hydraulic model were to be developed from field surveys. Due to the large number of streams studied, and the increasing numbers of bridges and culverts, it was necessary to perform two cross section survey contracts instead of one. So, the total amount of funding that was spent on surveys was just over $100,000, instead of $60,000, as originally planned. Therefore, the next item in the task list had to be sacrificed, as described below. Also, despite the increased funding for surveys, some creek crossings were modeled based on bridge and culvert plans, or measured by the Corps during site visits.

Task 7 – Define Stormwater Conveyance System

The Stormwater Conveyance throughout the watershed was determined to be a lower priority task than obtaining accurate creek channel information with field surveys. Therefore, as stated above, this task was completely removed from study, with the approval of the local project sponsors. Instead of surveying stormwater pipes, the areas in the watershed with quickened runoff through stormwater systems were modeled with the appropriate hydrologic parameters in the HEC-HMS program. This was made simpler using the detailed land use information available in GIS format.

Task 8 – Calibrate and Verify Models

Calibration of the hydrologic and hydraulic models took place according to the methods that were outlined in the original scope of work. Actual rainfall, streamflow, and gage height data were used to verify the accuracy of the HEC-HMS and HEC-RAS models. High water marks recorded on site during the storm of January, 2005 were especially useful for the HEC-RAS model calibration. However, as described in **Section 7** and **Section 8**, data inconsistencies and other variables made it unfeasible to make use of all calibration storm data.

Task 9 – Perform Base Condition Modeling

The base condition modeling effort took place as planned, analyzing eight different storm frequencies over the entire Dardenne basin. Peak flow rates and flood heights were calculated for every stream greater than one square mile in drainage area. The 100-year floodplain limits were mapped and compared to the original floodplain limits determined by the St. Charles County Flood Insurance Study. One item of note is the lack of a "floodway" calculation for this study, which was never planned to be a project feature.

Task 10 – Perform Forecasted Condition Modeling

The forecasted condition modeling immediately followed the development of the base condition. The same flood frequencies were analyzed for a forecasted condition that included changes to the hydrology based on the planned developments in the watershed. The original scope of work did not specify a set time period for the forecasted condition, so the time frame for the forecasted conditions model varied based on the information that was available from each individual city or county office

5. Description of the Project Area

This section describes the project area for the Dardenne Creek Watershed Study in detail. The limits of the HEC-HMS hydrologic model are same as the extent of the watershed, which encompasses all areas that drain into the Dardenne Creek tributaries and Dardenne Creek itself. The HEC-RAS hydraulic model covers all streams in the watershed that drain at least one square mile of area. The streams are studied from the upstream end, at the point where one square mile of drainage is achieved, and downstream to the mouth.

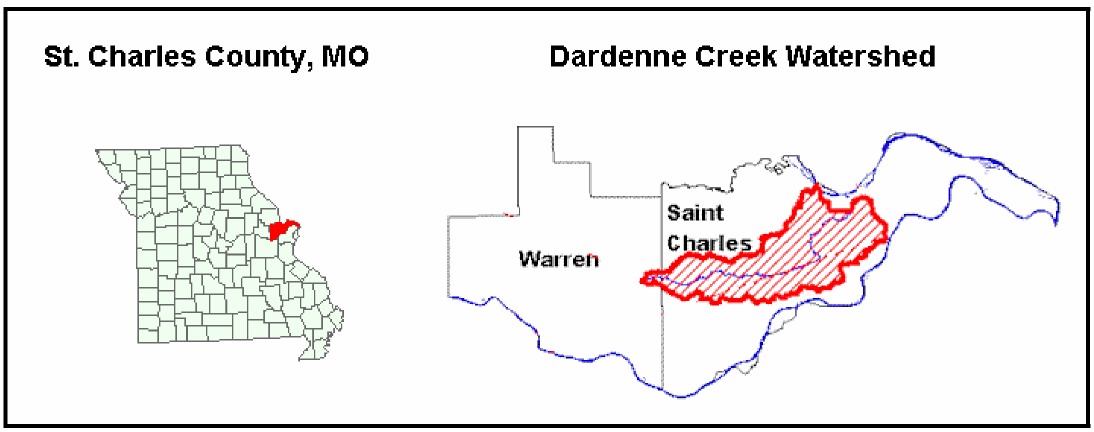

Figure 5.1 – Dardenne Creek Project Area

The Dardenne Creek watershed occupies just over 150 square miles, and drains the runoff from almost 30% of St. Charles County. The comparative size of the watershed (and the counties that it occupies) is shown above in **Figure 5.1**. The main stem of Dardenne Creek originates in the east central portion of Warren County, but only about 1% of the watershed actually falls within Warren County. From there, Dardenne Creek flows generally to the East, and just downstream of Highway 40/61, it enters a reach that is straightened and channelized. Near Mid Rivers Mall Drive, the creek turns north and flows through Old Town St. Peters on its way to the Mississippi River. The lower end of Dardenne Creek and parts of four tributaries are lined by levees to protect the floodplain areas from Mississippi River backwater. The watershed can be neatly divided into three characteristically different regions, which have been called the Lower, Middle, and Upper Dardenne basins. Here is a brief description of the characteristics of each region:

Lower Dardenne:

The Lower Dardenne Basin is the Mississippi Floodplain area protected by levees, as described above. The western portion is primarily used as farmland, and is also home to several hunting clubs. There is little impervious area in this region. However, the eastern portion of the Lower Dardenne Basin, near the Cole and Boschert tributaries, is considerably more developed. The developed areas in this region are primarily industrial. One fairly large development coming to the region in the near future is the Lakeside 370 development in St. Peters, which will include commercial sites and a 300-acre park.

Middle Dardenne:

The Middle Dardenne Basin includes most of the area that falls between Interstate 70 and Highway 40/61. At present time, this is the most highly developed portion of the watershed. The bulk of the city limits of St. Charles, St. Peters, O'Fallon, Cottleville, and Dardenne Prairie fall within this region. The land use in the Middle Dardenne Basin is primarily a mix of residential and commercial, with some parks and open space. The region contains several existing municipal parks, and Great Rivers Greenway is currently developing over 200 acres of greenway along the creek. While most of the region is developed, there are still some significant residential developments planned, as well as the Page Avenue extension, which is in the planning stages at the time of this report.

Upper Dardenne:

The Upper Dardenne Basin is the least developed area in the watershed, so it also has the greatest land area remaining for future development. A significant portion of the region contains land plots that are zoned for residential use in the future. However, the Missouri Department of Conservation maintains the Busch Wildlife Management Area in this region, which occupies almost 7000 acres, or about 11 square miles, and contains several lakes and forested hunting areas.

As stated at the beginning of this section, all tributaries to Dardenne Creek with a drainage area of greater than one square mile were also covered in the study. The only exception to the one square mile rule is the local runoff behind levees near the mouth of Dardenne Creek. Other than the direct inflow from Cole, Sandfort, and Spencer Creeks, all runoff to Dardenne Creek in the area of the Mississippi River Floodplain enters the creek through gravity drains and/or pumps.

In this area of the Mississippi Floodplain, there are some areas larger than one square mile that do not form a stream channel, and cannot be studied with a one-dimensional steady flow model such as HEC-RAS. On all data tables and plots in this report, these floodplain areas are referred to with the abbreviations F1-F6. The names of all streams in the study were given a two or three character code for use in data tables and these codes are listed here in **Table 5.1**. The table lists all streams in order from the downstream end to the upstream end of the system.

Table 5.1 – Dardenne Watershed Streams and Abbreviation Codes

Code:	Stream:	Code:	Stream	Code:	Stream:
DA	Dardenne Creek	CO	Cole Creek	BO	Boschert Creek
EC	East Cole Creek	SF	Sandfort Creek	WSF	West Sandfort Creek
SP	Spencer Creek	WSP	West Spencer Creek	ESP	East Spencer Creek
T1	Tributary 1	ED	East Dardenne	T2	Tributary 2
TA	Tributary A	T3	Tributary 3	T4	Tributary 4
BA	Baltic Creek	T7	Tributary 7	CR	Crooked Creek
T9	Tributary 9	EB	East Tributary B	WB	West Tributary B
SC	Schote Creek	T13	Tributary 13	OL	Old Dardenne
T15	Tributary 15	T19	Tributary 19	OD	Oday Branch
KR	Kraut Run	T17	Tributary 17	CU	Cunningham Branch
LD	Little Dardenne				

6. Data Collection and Mapping / GIS

The early stages of the watershed study were mainly devoted to data collection. In order to improve on the older versions of the hydraulic models, it was important to obtain the most accurate and up to date geometric data to define the watersheds and creek channels. New topographic maps were developed for the watershed definition, and a contract for cross section surveys enhanced the knowledge of the creek channels. In addition to topographic mapping and cross section surveys, a large amount of data was obtained in Geographical Information Systems, or GIS format. Any remaining physical information about the creeks was obtained with field investigations. All aspects of data collection are described in the following sections. Unless otherwise noted, all data collected for the study can be found on the DVD-ROMs included with this study report. An inventory of all data collected can be found in **Appendix A1**.

6.1 Terrain Mapping and Aerial Photography

As stated in the introduction, the most recent existing flood studies done in the Dardenne Creek Watershed are between 10 and 30 years old. The standard practice for hydrologic engineering models in that time frame was to use topographic maps produced by the United States Geological Survey (USGS), which are also known as 7.5 minute Quad maps. While USGS Quad maps typically have a 10 or 20 foot contour interval, advancements in Geospatial Engineering allow for the creation of topography with a much better precision. Therefore, the new Dardenne Watershed Study used a terrain model that is accurate enough to produce four foot contours.

To develop the new terrain model for the Dardenne Creek study, the Corps contracted the work out to the Sanborn Mapping Company in the Spring of 2004. Sanborn conveniently had flown some aerial photography over St. Charles County in March of 2004 for another project. The existing photography was deemed to be appropriate for the study, so the remaining tasks were to convert the photos to digital files and develop elevation data to suit the needs of the Dardenne Study.

The Corps submitted a rough estimate of the Dardenne Creek Watershed to Sanborn, to indicate the area for the required terrain mapping. Through a process called photogrammetry, the digital aerial photos were used to derive a digital terrain model, or DTM. This terrain model includes elevation points and breaklines, which define artificial boundaries such as roadways. The data was provided with the NAD 1983 Horizontal Datum, in the Missouri East State Plane Coordinate System. The vertical data was referenced to the National Geodetic Vertical Datum 1929 (NGVD 29). The same reference datums are used for all data that was provided on the DVD accompanying this study, including all prior FEMA flood studies.

An example of the terrain data and aerial photos that were produced with this mapping contract is shown in **Figure 6.1.1** below. The image is a screen capture from the ArcGIS window with both the aerial photo and terrain data. The blue diamond-shaped symbols depict elevation points, and the bright green lines are the breaklines. Note the detail of the aerial photography, and the spacing of the elevation points, which varies based on the steepness of the terrain. The area in the photo is centered over the junction of Dardenne Creek and Baltic Creek, near Mid Rivers Mall Drive (visible on the left side of the image). The breaklines trace the centerline and banklines of the creeks, as well as the outline of lakes, roadways, and other features. The breaklines also contain elevation data, and are necessary for an accurate portrayal of the flow of water over the surface of the watershed.

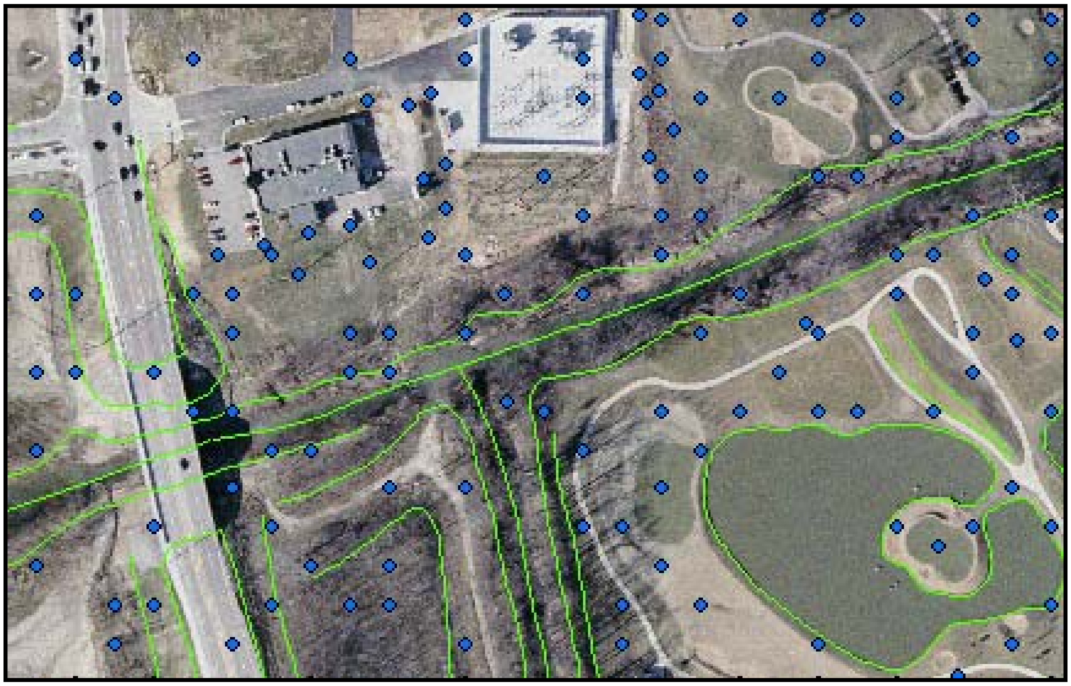

Figure 6.1.1 – Sample of Terrain Data and Aerial Photos

Sanborn submitted the final terrain data and aerial photos to the Corps in DVD-ROM format. Due to the extremely large file sizes, these aerial images cannot be easily transmitted in electronic format with this report. There are a total of 757 aerial photos covering the watershed, and each file takes up 72 MB of disk space in “TIF” format. By contrast, the terrain model data is in ArcGIS shapefile format, and the files covering the entire watershed take up just over 1 GB. Therefore, the terrain data is submitted with the other digital files on DVD for this project. Selected aerial photos can be made available on DVD at the request of any interested party.

6.2 Flood Insurance Studies and Maps

The watershed study results were compared with the published results of the St. Charles County Flood Insurance Study (SCCFIS). The criteria for the comparison were the flooded area maps for the 100-year storm. Working copies of the maps already were available in the offices of the Corps, but digital copies of the maps were required for the flooded area comparisons. As a Federal agency, the Corps had the ability to download all of the required FEMA maps in digital format free of charge.

Backup copies of the FIS map files were kept in tact with the borders and legend information, and the other copies of the files were cropped in order to represent a continuous flooded area for comparison to the results of the new models. The actual FEMA map comparison and further discussion of the results can be found in **Section 9** of this report.

In addition to the maps from the St. Charles County Flood Insurance Study, the peak flow tables and water surface profile plots were also referenced. These tables and plots are contained in the published volumes from the SCCFIS. The peak flows were used for a frame of reference when comparing water surfaces for a particular reach of stream. Given the varying methods of analysis and changed watershed conditions, some peak flows from the HEC-HMS model were found to be higher or lower than the FEMA published flow values. By noting the differences in flows, a better explanation could be made for the variation between the old and new flooded area plots.

6.3 Cross Section Surveys

Although the terrain model described above covers the entire Dardenne Creek watershed, the elevation data for the stream channels could not be determined if the creek bed was underwater during the aerial photography. This presents a problem, because the accuracy of the HEC-RAS model results depended on getting the most up to date geometric information in the creek channels. Although there are several existing hydraulic models containing creek cross sections, they are likely to be outdated due to the changes in the watershed since the creation of the models. Therefore, field surveys would be required to define the creek channels throughout the system. Field surveys could also be utilized to determine bridge and culvert geometry.

As described in **Section 4** of this report, the original funding amount allotted for cross section surveys was $60,000. Unfortunately, that original estimate fell far short of the amount that would be required for a full survey of every stream and bridge in the system. Therefore, the scope of work was modified to allow for field surveys in the amount of about $100,000. Even though this change made it possible to survey more sections, certain aspects of the bridge surveys had to be eliminated from the contract. Any remaining information could be obtained through field investigation or bridge and culvert plans, as described in **Sections 6.6** and **6.7** below.

Woolpert LLP was the firm contracted to do the cross section field surveys, in two separate contracts. The survey contracts specified the same horizontal and vertical datums that were used for the terrain mapping and aerial photography, which were MO East State Plane and NGVD 1929. Cross sections were to be taken to a point 50 feet outside the high bank of the channel on both sides. Each cross section had a minimum of 8 points, as well as a survey point with every change of grade across the section.

The cross section points were submitted as “xyz” points in an ASCII text file. In this fashion, the exact final location the elevation points could be viewed in the ArcGIS program. In addition, the section data was provided in Microsoft Excel format, as a station and elevation pair for each point. For a sample cross section, see **Figure 6.3.1** below. The “station” component of the cross section is a measure of the distance across the section from left to right, looking downstream.

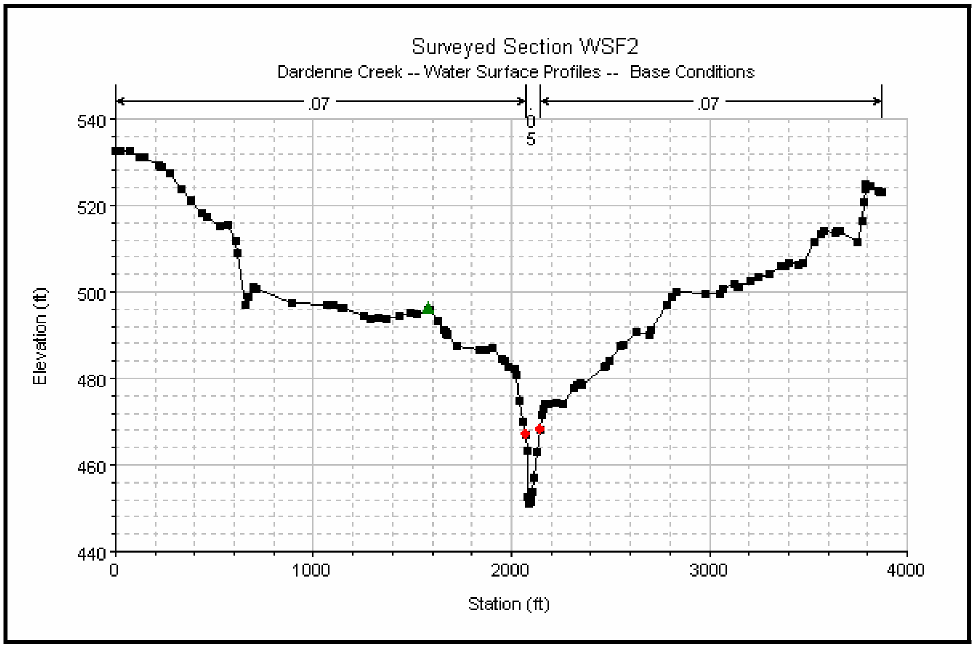

Figure 6.3.1 – Sample Cross Section Plot (from HEC-RAS)

6.4 Data from Geographical Information Systems (GIS)

The primary goal for obtaining additional information in GIS format was to supplement the terrain data with watershed characteristics that are necessary for determining hydrologic model parameters. Two primary GIS data sets were obtained for the project, and they were the USGS land use data and the NRCS soil surveys for St. Charles County.

The USGS land use data was obtained from the Internet at the following web address: http://seamless.usgs.gov/. This is the site of the USGS’s Seamless Data Distribution system. Through this site, the user is able to query to find data on a specific block of area anywhere in the United States. The data available includes topography, roads and highways, city and county limits, stream centerlines, and land use coverage from 2001. The land use data was found to be generally suitable for the purposes of this study. If the current land use conditions in any regions were found to differ greatly from 2001 data, this was taken into consideration in the hydrologic parameter estimation.

Soil data for the Dardenne Watershed was obtained from the National Resource Conservation Service (NRCS), which was formerly known as the Soil Conservation Service (SCS). The SCS loss rate method estimates hydrologic parameters for a given land use and soil type. The soil types are divided into 4 categories called the Hydrologic Soil Groups, which are designated as A, B, C, and D. The description of the 4 hydrologic soil types are shown here:

Soil Group:	**Description:**
A	Sandy and well drained soils
B	Sandy loam soils
C	Clay loam or shallow sandy loam
D	Poorly drained, heavy plastic clay (soils that swell when wet)

A more detailed description of the hydrologic soil groups is available on the NRCS website at http://soils.usda.gov/technical/manual/tables/table3-9.html.

6.5 Rainfall and Streamflow Data

In order to calibrate the hydrologic and hydraulic models, actual historical storm events were researched and applied to the models. Therefore, it was important to obtain accurate rainfall and streamflow data where it was available throughout the watershed. This section describes the sources and types of data that were utilized.

Rainfall Gages:

Typically, the most reliable source of rainfall data is the National Weather Service. The National Climatic Data Center (NCDC) keeps hourly rainfall records for stations throughout the United States. Unfortunately, the limited number of gages resulted in only one gage being used for this project. The gage was located in the town of Wentzvillle, just northwest of the extents of the Dardenne Watershed. The records from this gage were downloaded in table format for the calibration storms, which are described later in the report in **Section 7.2.2**. All available rainfall data is presented in **Appendix A4**.

Hourly Rainfall data was also available at a Corps of Engineers river gage station on the Missouri River in St. Charles. The Corps' historical databases are not available to the general public over the Internet, but the Water Control section of the St. Louis District was consulted to obtain the necessary rainfall records. Similarly, the city of St. Peters was able to provide the Corps with rainfall records from their Wastewater Treatment Plant just north of Interstate 70 near Mid Rivers Mall Drive. All hourly gage readings were incremental gages, reporting a value in inches for the rainfall in any given hour recorded.

While the hourly rainfall data is ideal for the purposes of hydrologic modeling, the three hourly gages described above were not sufficient to represent rainfall over the entire watershed. During the course of data acquisition from the city of St. Peters, the "Weather Underground" website (www.wunderground.com) was brought to the attention of the Corps by St. Peters city personnel. Three additional rainfall gages were found that measured rainfall intensity during a storm. These gages were located in Dardenne Prairie, Weldon Springs, and Harvester, Missouri. The rainfall intensity data was converted to incremental rainfall, and added to a data file containing all rainfall data. The water data is stored in a DSS file, which is a data format developed by the Hydrologic Engineering Center, for use with their hydrologic and hydraulic software products.

Finally, two additional NCDC gages were investigated and used for less recent storms, when the Weather Underground and St. Peters Treatment plant gages were unavailable. These two NCDC gages were located in St. Peters and Weldon Springs, and provided daily rainfall readings during the storms. The total storm gage option was used for the hydrologic modeling in HEC-HMS, as described in **Section 7.2.2**. The location in Latitude and Longitude (LAT/LONG) for the rainfall gages is shown here in **Table 6.5.1** (excluding the total storm gages).

Table 6.5.1 – Rainfall Gage Locations

Gage Location:	**Source:**	**Type:**	**LAT:**	**LONG:**
Dardenne Prairie	W. Underground	Intensity	38° 46.5'	90° 45'
Harvester	W. Underground	Intensity	38° 45'	90° 33.5'
St. Charles	USACE	Hourly	38° 47'	90° 28.5'
St. Peters	S.P. Treatment Plant	Hourly	38° 48'	90° 36.5'
Weldon Springs	W. Underground	Intensity	38° 43'	90° 39'
Wentzville	NWS-NCDC	Hourly	38° 49'	90° 51'

Streamflow Gages:

Only two locations in the entire Dardenne Watershed have USGS streamflow gages. The O'Fallon gage is located at the Highway K bridge over Dardenne Creek, and the Old Town St. Peters gage is located on Dardenne Creek near Highway C and Interstate 70. These two gages record both streamflow in cubic feet per second (cfs) and gage height in feet. The gages were installed by the USGS in November of 1999, and are maintained through partial funding provided by local interests.

Most gage heights can be converted to an elevation using a gage datum, or gage zero elevation. However, the establishment of a gage datum was not included in the original plans for the Dardenne Creek gages. Therefore, high water marks during the storm event of January, 2005 were used to estimate flood heights. Although the gages record a stage value to the hundredth of a foot, the elevation estimates were made to the nearest tenth a foot, which is sufficient for the purposes of model calibration. The flood elevations were determined in reference to known elevations of nearby bridges. The calculation of the gage zero estimates are shown here: (Gage Zero = Elevation – Stage)

Gage:	**Elevation:**	**Jan 2005 Peak:**	**Gage Zero:**
O'Fallon	478.7 ft	16.8 ft	461.9 ft
St. Peters	448.6 ft	20.8 ft	427.8 ft

Data was obtained for the entire period of record for both streamflow gages. The gages record data every 15 minutes, which is more often than the available rainfall data. The final application of rainfall and streamflow gages for calibration is discussed in **Section 7**, covering the Hydrologic Modeling Methodology. More information regarding these streamflow gages can be found on the following USGS websites devoted to the gages:
http://waterdata.usgs.gov/mo/nwis/nwisman/?site_no=05514840 [O'Fallon Gage]
http://waterdata.usgs.gov/mo/nwis/nwisman/?site_no=05514860 [St. Peters Gage]

As with the rainfall data, the streamflow gage data has been converted to HEC-DSS format for use with the hydrologic models. This file is also included on DVD. The gage heights and streamflow data for the calibration storms are included in **Appendix A5**. Other pertinent information concerning the stream gages is shown here in **Table 6.5.2**.

Table 6.5.2 – Streamflow Gage Information

Name:	**Drainage Area:**	**Latitude:**	**Longitude:**
O'Fallon / Highway K	61 square miles	38°44'25.3"	90°41'42.2"
Old Town St. Peters	102 square miles	38°48'12"	90°38'06"

6.6 Existing Plans and Computer Models

Bridge and culvert plans were obtained from the Missouri Department of Transportation (MODOT) and St. Charles County. These plans were used to supplement the data obtained through cross section surveys or field investigation and inspection. The Corps of Engineers contacted the studies and plans offices of MODOT and St. Charles County, requesting as-built drawings, if available, for locations on Dardenne Creek and its tributaries. The Corps requested the plan, profile, and cross section views, with respect to the creek in question. In cases where there was any doubt or ambiguity in the information presented in the drawings, the Corps verified data through field investigations.

Existing Hydrologic and Hydraulic Models were used as a reference for this study, in order to develop some initial hydraulic parameters, such as Manning's roughness values. The Corps of Engineers already was in possession of all available HEC-2 computer models for the St. Charles County Flood Insurance Study. HEC-2 was the precursor program to HEC-RAS, and it did not contain a graphical user interface like RAS does. Therefore, the data files are strictly text-based. These data files are included on the data DVD for the project. Also included on the DVD are two HEC-1 data files, which are part of a hydrologic analysis for Dardenne Creek. HEC-1 is the DOS-based precursor program to HEC-HMS. However, the lack of detail in the Dardenne model made it difficult to apply any information to the new modeling effort. An inventory of all previous model studies is included in **Appendix A3**.

6.7 Data Acquired by Field Investigation

Over the course of the 3-year study, about 17 site visits were made to investigate different aspects of the Dardenne Creek Watershed. The goal of these site visits was to photograph and record the geometric characteristics of the streams and their contributing watersheds. It was important to obtain any remaining bridge and culvert geometry that wasn't obtained through surveys or bridge plans. As mentioned in **Section 4**, the Dardenne Creek system was also inspected and videotaped on two occasions by helicopter. This section describes the information obtained through field investigation.

For each site visit to a bridge or culvert crossing, the following information was obtained: the bridge deck width (in the direction of flow of the creek), bridge opening width and height, bridge deck thickness, bridge opening roughness, culvert size and length, culvert material type, headwall type and size, wingwall type and angle from parallel. These measurements were made with standard field equipment including a hand level, tape measure, and folding ruler. A handheld Global Positioning System (GPS) unit was taken along to verify the location of the site being studied. A 4-Megapixel digital camera was used to photograph the upstream and downstream views of the bridge or culvert, as well as the view away from the crossing in either direction along the creek. A sample of photographs taken is included in the report as **Appendix A2**. Additionally, all photos from the site visits are included on the DVD submitted with this report.

The two helicopter surveys of the Dardenne Creek watershed offered a unique opportunity to get a quick overview of a large portion of the creek, as well as a few tributaries of interest. The first trip took place on June 8th of 2004, and the 2nd trip was flown on March 1st of 2005. A Geo-referenced DVD was recorded on both occasions, so the exact location of any portion of the video would be known. Using a software package called GeoVideo along with ArcGIS, the path of the helicopter flight can be viewed over any GIS theme or map available. This was a tremendously useful tool for analyzing the large volume of video that was available. The helicopter trips also allowed engineers to see areas of the watershed that were not easily accessible by road. For example, the erosion control methods for a development under construction were clearly visible, in **Figure 6.7.1** below. DVD copies were distributed shortly after each helicopter trip, and the Corps of Engineers can provide additional copies upon request.

Figure 6.7.1 – Erosion Control for Residential Development near East Tributary B

An intense flood event on Dardenne Creek in January of 2005 also gave engineers an interesting opportunity to gather additional data that was relevant to the study. Heavy rainfall occurred during an unusual time of the year, when the ground was partially frozen with saturation from previous rainfall. Due to that saturation, an extremely high portion of rainfall immediately became runoff to the creek, instead of infiltrating. A local agricultural levee on the left bank of Dardenne Creek was overtopped and partially eroded just downstream of Highway C in St. Peters. Photographs from the levee break are included in **Appendix A2**.

Several bridges and other sites were inspected and photographed on January 6th, 2005, at a time that was about 12 hours after the peak flow of this significant storm event. The main benefit of visiting the site so soon after the flood is the ability to obtain accurate high water marks (HWM). Just after a flood passes, water stains can be easily seen on bridge piers or culvert walls. In areas with grass and other vegetation, the high point of the stream flow could be determined to be the level where the vegetation had been matted down by the rapidly flowing water. **Appendix A6** contains a list of all HWM elevations recorded.

7. Hydrologic Modeling Methodology

The HEC-HMS model formulation involved two major components. The first component was to utilize the ArcView program to gather the appropriate data and create the HEC-HMS model files with the GeoHMS extension of ArcView. The second component involved the fine tuning of the HEC-HMS modeling parameters in order to calibrate and operate the model. The details of each step of the process are described in this section.

7.1 Model Creation using HEC-GeoHMS / ArcView Software

The GeoHMS extension of the ArcView GIS program has the ability to delineate watershed boundaries, and compute other physical watershed characteristics, such as the basin slope and the longest flow path for a particular portion of the watershed. The accurate delineation of watersheds is a very important factor in model accuracy, and any other physical basin characteristics also improve modeling results.

In order to begin the GeoHMS process, the program requires a Digital Elevation Model (DEM) for completing the watershed computations for a desired area. A DEM is a type of map coverage in a grid format, meaning that the known elevation points are arranged in a grid in the X-Y plane. For each square of the grid, one elevation point represents the average elevation in the area covered by the square. Therefore, the smaller the grid is, the more accurate the terrain will be represented. The terrain model data from the Sanborn mapping contract was delivered in ESRI's Shapefile format, so a conversion had to be made to produce the desired grid, or DEM. A 30-foot cell size was chosen, based on the typical spacing of known elevation points in the terrain model. The best available grid size for terrain data from the USGS is typically 30-meters, so the data used for this project was significantly more accurate than it would have been without the terrain mapping contract to acquire the data. **Figure 7.1** below shows a sample of DEM data from roughly the same location as **Figure 6.1.1**, near the mouth of Baltic Creek. Note that this relatively flat area does not show a strong definition of the terrain data.

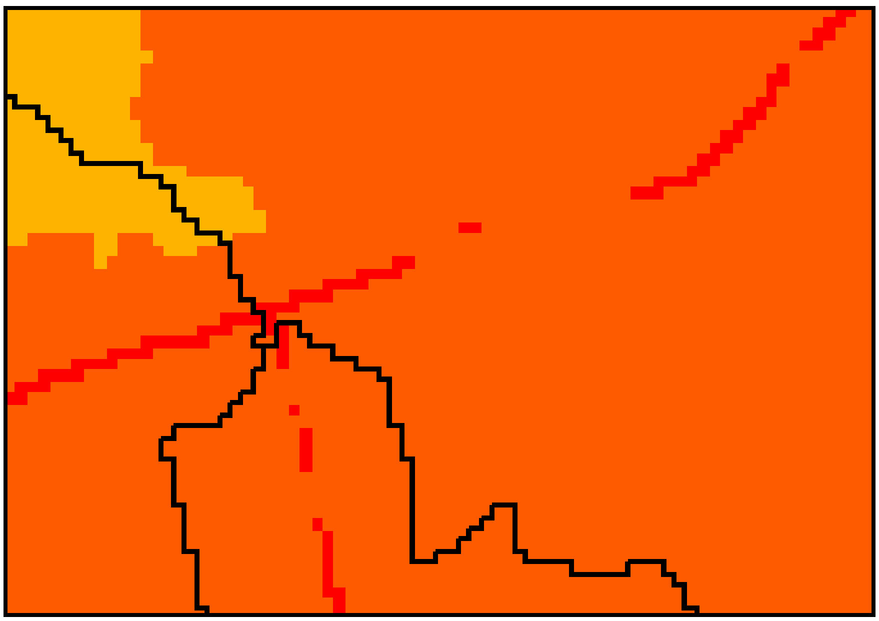

Figure 7.1 – Sample from the Digital Elevation Model (DEM) for Dardenne Creek

GeoHMS uses a method called the 8-point Pour model to delineate watershed areas. For every square in the DEM, the elevation of a point is compared to the 8 squares of the grid immediately surrounding it. Hypothetically, as rain falls on this particular grid, or moves through the grid on the surface of the ground, the water will seek the lowest possible adjacent point. This elevation comparison is repeated for every point in the grid, for both the Dardenne Creek watershed area and the surrounding area. The actual watershed delineation is performed by defining the project outlet point. The outlet is the most downstream point in the study area, which is the mouth of Dardenne Creek at the Mississippi River. The entire watershed is then defined as the area containing all of the grid points from the entire terrain grid that drain downstream to this point.

For the purposes of hydrologic modeling, the entire Dardenne Creek watershed area, at just over 150 square miles, is too large to consider as an individual element. Therefore, the watershed is divided into smaller portions called Subbasins. Using the criteria from our project scope, all tributary streams would be studied if they had a drainage area of one square mile or greater. Consequently, a size of one square mile was used as a guide for creating Subbasins. In addition to these smaller divisions of the watershed, basins were also divided wherever a tributary stream comes into Dardenne Creek. This way, the peak flows could be calculated for each tributary stream, for use with the hydraulic modeling, or HEC-RAS model. A plot showing the delineation of all Subbasins can be seen in **Appendix B2**.

After watershed delineation took place, the final pieces of information were computed for each Subbasin. The basin slope and longest flow path were computed in order to determine the time of concentration of the watershed. The Time of Concentration determines how quickly water can move through the system, and it is computed for each Subbasin. Also at this time, the land use and soil data was viewed for each Subbasin, and an SCS curve number was computed based on these factors. The SCS curve number determines how much rainfall is converted to runoff for each Subbasin. These Subbasin parameters will be discussed in more detail in the **Section 7.2.1** below.

The final step in the GeoHMS process is the actual creation of the HEC-HMS model files. Using all of the data parameters, the ArcView GIS program produces a basin model schematic, which links together all of the Subbasins and stream reaches, and places them in a computer file called a Basin model file. The location of each Subbasin is defined by the centroid of the area contained by the basin. Using the Geo-referenced GIS data in this manner, the basin schematic is geographically accurate, as shown in the HEC-HMS program. A background map or other GIS data can also be viewed in the HMS window. This is helpful for viewing particular features of any area of the watershed. The basin model schematic for the Dardenne Creek HEC-HMS model is displayed in **Appendix B1**. Within the HEC-HMS program, all of the basin elements can be selected and all pertinent data can be viewed or changed as needed. The final basin model consisted of 157 Subbasins and 126 routing reaches.

7.2 Hydrologic Modeling using HEC-HMS Software

After the HEC-HMS model is created with the ArcView GIS program, other features are added to the model to represent storm events over the watershed. Final changes to basin characteristics can be made, and meteorologic data for the desired storms is setup. The following sections describe the process that was used to complete the HEC-HMS modeling for the Dardenne Creek study.

7.2.1 Basin Characteristics

As stated above, a good portion of basin data comes directly from the geometric information available in the terrain model. However, certain hydrologic parameters need to be computed or estimated to finalize the data that is required for the program to run. This section will describe the remaining data parameters that are entered into the HMS program.

SCS Loss Rate Method:

As stated earlier, the SCS method was used for the calculation of rainfall losses. Infiltration is the primary component of rainfall losses, and other components such as evaporation can be assumed to be negligible, except in rare cases. The SCS method applies a “curve number” that represents the likelihood of rainfall being converted to runoff in streams. The curve numbers for the Dardenne Creek model were selected based on the GIS data for land use and soil type covering each Subbasin in the HMS model. Another parameter required for the SCS loss method is the Percentage of Impervious area. This percentage can range from around 20-40% for residential areas, or up to 50-90% for commercial and industrial areas. However, due to the size of a typical Subbasin in the Dardenne model, very few basins were found to be entirely made up of one land use type. Therefore, an estimate was made by inspecting the available aerial photography. The final parameter is the Initial Abstraction, which is calculated from the SCS curve number. The equations for this calculation are shown below in **Figure 7.2.1**. All final values can be found in **Appendix B3**.

$$S = \frac{1000}{CN} - 10 \qquad I.A. = c \times S$$

S is the potential retention factor, calculated from the curve number (CN).
I.A. is the initial abstraction, and c is a constant value, based on recent rainfall.
(A value of 0.1 was used as the constant for the Dardenne Creek modeling.)

Figure 7.2.1 – Calculation of Initial Abstraction from SCS Curve Number

Clark Transform Method:

The hydrograph transform method is the way that HEC-HMS computes a hydrograph pattern based on the timing of rainfall and the ease of flow through each basin. In the Clark Transform method, the Time of Concentration, or TC is the main parameter used. The TC represents the time it takes for a drop of water falling on the most remote portion of a basin to flow through the system and reach the basin outlet. The travel time is broken up into three components: sheet flow, shallow concentrated flow, and channel flow. A speed and distance is associated with each type of flow, based on the slope of the basin, the land use type, and the channel roughness. When the travel time is computed (as distance divided by speed) and the 3 portions are added to arrive at the total TC. A Microsoft Excel spreadsheet was used to automate the calculations, and the Excel file is included on the DVD with the project data. The other parameter used in the Clark method is the Storage Coefficient, R. The R values are calculated by the following equation: R / (TC + R) is constant for a region. Since the Dardenne Creek watershed covers a large area of varying terrain, the constant that was used ranges from 0.3 to 0.5. **Appendix B4** shows the final parameters used for the Clark Transform method data.

Recession Baseflow Method:

Since the rainfall-runoff model only produces runoff in a stream if there has been recent rainfall, a baseflow method is required to compute an average flow in the creek for times when it has not rained recently. Even in the dry months, many streams are large enough to have a certain amount of flow coming into the stream from groundwater. This parameter is very difficult to estimate, but the overall effect of baseflow throughout the system can be reasonably calibrated by looking at the low flow portions of the USGS stream gages. The average baseflow in each basin can be estimated as 1 CFS per square mile of drainage area. However, the final calibration was achieved with a factor of 0.6 CFS per square mile. In addition to the low flow portion of the hydrograph, the Recession Baseflow Method computes the receding portion of the hydrograph, as the storm runoff in each basin returns back to the low flow amount. A constant reduction in flow is applied for each day of the storm, and a reduction factor of 0.5 was used. A percentage of the peak flow is used to determine the point in the hydrograph when the runoff stops and the baseflow begins. The ratio of baseflow to peak flow used was 0.05, or 5% of the peak. These values resulted in the best correlation to observed flow data from the USGS gages. The table with the final baseflow data can be seen in **Appendix B5**.

Modified Puls Routing Data:

A hydrograph routing method is required to combine the flow from each Subbasin in the watershed, and transfer the flow from one reach of stream to the next one downstream. The time delay, as well as the storage capacity in a reach, will usually result in the attenuation of the hydrograph. This means that the peak flow is reduced, and the time of the peak flow is delayed to a later time. One highly accurate method of flow routing uses the actual geometric layout of each creek as the basis for the routing. This is called the Modified Puls method, and the required input is a storage-discharge curve for every reach. Therefore, the cross-section geometry that is available in the HEC-RAS geometry was the best available data for routing. By running a range of flows in the HEC-RAS program, the water surface elevations and storage capacity were computed for every reach in the HMS model. The tables with the storage-discharge relationships can be found in **Appendix B6**.

Reservoir Data:

Two reservoirs in the Dardenne Creek Watershed were determined to be large enough to have a significant effect on peak flows during storm events. Also, the hydraulic models were required to extend upstream of their location. Both lakes are located in the Busch Wildlife Management Area operated by the Missouri Department of Conservation (MDC). A site visit was made to the area, and more detailed information was requested and received from a representative of MDC. A modification to the overflow spillway of one of the two lakes was planned in the early stages of the Dardenne study, so the plans for the new spillway were obtained. That way, the correct lake outlet condition could be modeled, because it was constructed before the completion of this study.

"Lake 33" is located on Kraut Run, just west of the Highway 40/61 crossing over Dardenne Creek. Lake 33 has a surface area of nearly 200 acres, and the outlet is controlled by a U-shaped overflow channel. A photo of the Lake 33 outlet spillway is shown here in **Figure 7.2.2**, and additional photos can be found in **Appendix A2**.

Figure 7.2.2 – Lake 33 U-Shaped Overflow Spillway

Lake 35 is located on Schote Creek, just upstream of the creek's crossing under Highway 40/61. The surface area of Lake 35 measures about 50 acres, and the lake outlet consists of a small morning glory spillway that drains water from the surface of the lake and out of a pipe through the dam (**see Figure 7.2.3** below). The newly constructed overflow spillway for Lake 35 is rock lined and measures 130 feet wide at the base.

Figure 7.2.3 – Lake 35 Morning Glory Overflow Structure

The outlet condition of each reservoir was investigated and weir equations were used to estimate the outflow for a given elevation of the lakes. The storage capacity of these reservoirs was also represented in the HEC-HMS program, and the final storage-outflow curves can be found in **Appendix B7**. With these data tables, the HMS program was able to route the upstream flow through the reservoirs and release the appropriate amount of flow based on the lake elevation. In the case of Lake 33, the outlet condition was unchanged from the time of the original FIS study, so the lake elevations from the FIS stream profile plots could be used as a guide for the expected performance of the reservoir in the final version of the model.

7.2.2 Meteorological Data

Two types of meteorological data were used for the HMS modeling of Dardenne Creek: actual rainfall from gage records and hypothetical rainfall for a given storm frequency. Actual rainfall was used for the calibration of the model, and hypothetical rainfall is used for the modeling of frequency storms for both the base and forecasted conditions. This section discusses the two types of rainfall data, and how they were applied to the HMS model.

Actual Rainfall Data:

As stated in **Section 6.5** above, there were various sources for actual rainfall data. Once the data was tabulated in hourly format, it was placed in a HEC-DSS format, which is a data base system for water data. With the DSS system, the records for each rainfall gage can be easily viewed, plotted, or applied to a hydrologic analysis with the HEC-HMS program. Rainfall from specific storm events was isolated in order to calibrate the HMS model to observed streamflow data. The calibration process is discussed in **Section 7.2.4** below. In order to best represent the rainfall over the entire watershed, multiple gages were used. However, the data from every gage will not be applicable to every Subbasin in the model, due to geographic location. The breakdown of rainfall data to the individual Subbasins is accomplished by the Thiessen Polygon method. Using this method, a zone of influence is defined, and GIS calculations are used to determine the percentage of the area of a Subbasin that is influenced by each gage. In this way, the most accurate portrayal of rainfall from a gaged event can be analyzed in HMS. **Appendix A4** contains the rainfall records used for each calibration storm. Note that some gages did not have records available for every storm. In those cases, the available hourly rainfall data was supplemented with total storm gages, which tabulate the total rainfall for a storm through daily data records. A sample hyetograph (or time series plot of rainfall) is shown here in **Figure 7.2.4**. Note that this hyetograph shows the actual hourly precipitation recorded from the St. Charles Rainfall gage. If the rainfall data used for the HMS model simulation were plotted, the location may have a composite rainfall computed from multiple gages. The simulation rainfall would also be broken down into 15-minute increments rather than the original hourly increment.

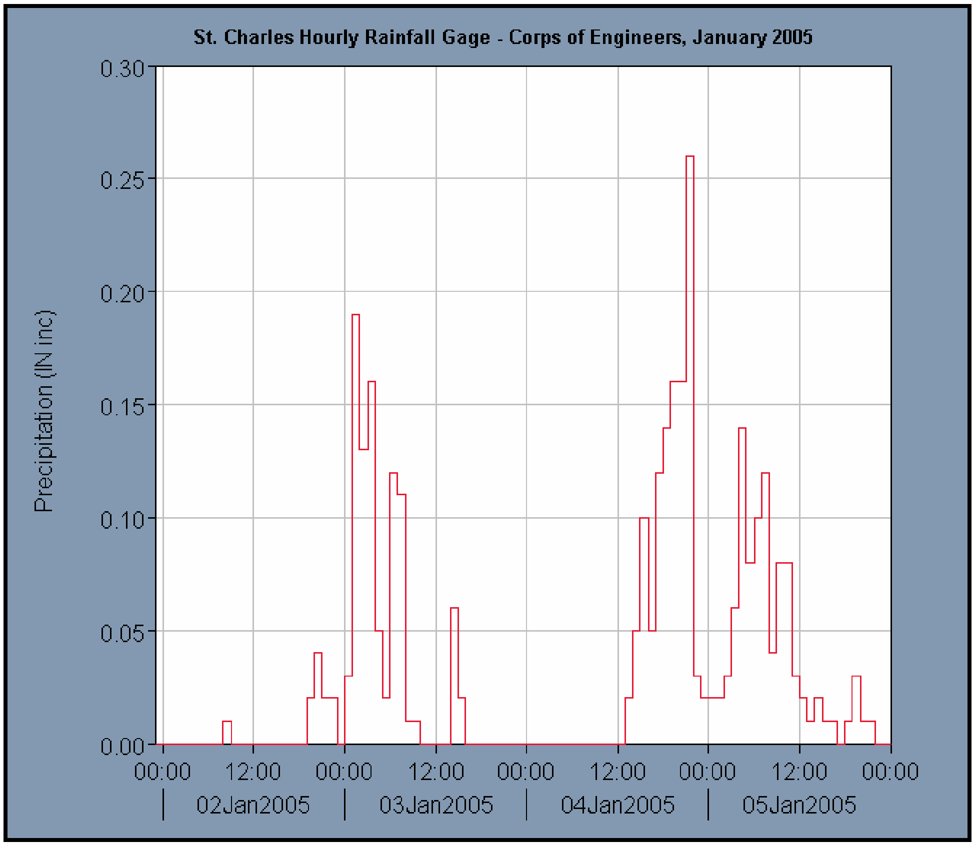

Figure 7.2.4 – Sample Hyetograph for Actual Historical Rainfall Event

Hypothetical Rainfall:

For the Dardenne Creek Watershed Study, eight frequency storms were to be used to analyze the base condition and forecasted condition of the watershed. The events used were the 2, 5, 10, 15, 25, 50, 100, and 500-year frequency. The HEC-HMS program allows the user to enter a duration-frequency curve for each rainfall frequency. Since a time step of 15 minutes and a 48-hour duration was used in the Dardenne Creek HMS model analysis, the duration curve starts at 15 minutes and goes up to 48 hours. This way, the appropriate rainfall amount is contained in the smallest time step of the storm, up to the entire duration. The rainfall duration-frequency curves were developed from the Rainfall Atlas of the Midwest, also known as Bulletin 71. The authors of the Rainfall Atlas researched storm types, durations, and intensities throughout the Midwest, and the findings of the report are presented for specific regions within each state. The results for the Northeast Prairie region of Missouri were consulted for application to the Dardenne Creek project. The only limitation of this hypothetical storm data is that the 15-year and 500-year storms are not included in Bulletin 71. In order to determine the appropriate rainfall amounts for these storms, the data had to be interpolated and extrapolated. A Microsoft Excel spreadsheet was used to plot and estimate the additional required rainfall amounts. The plot of the interpolated and extrapolated storm frequencies is shown here in **Figure 7.2.5**.

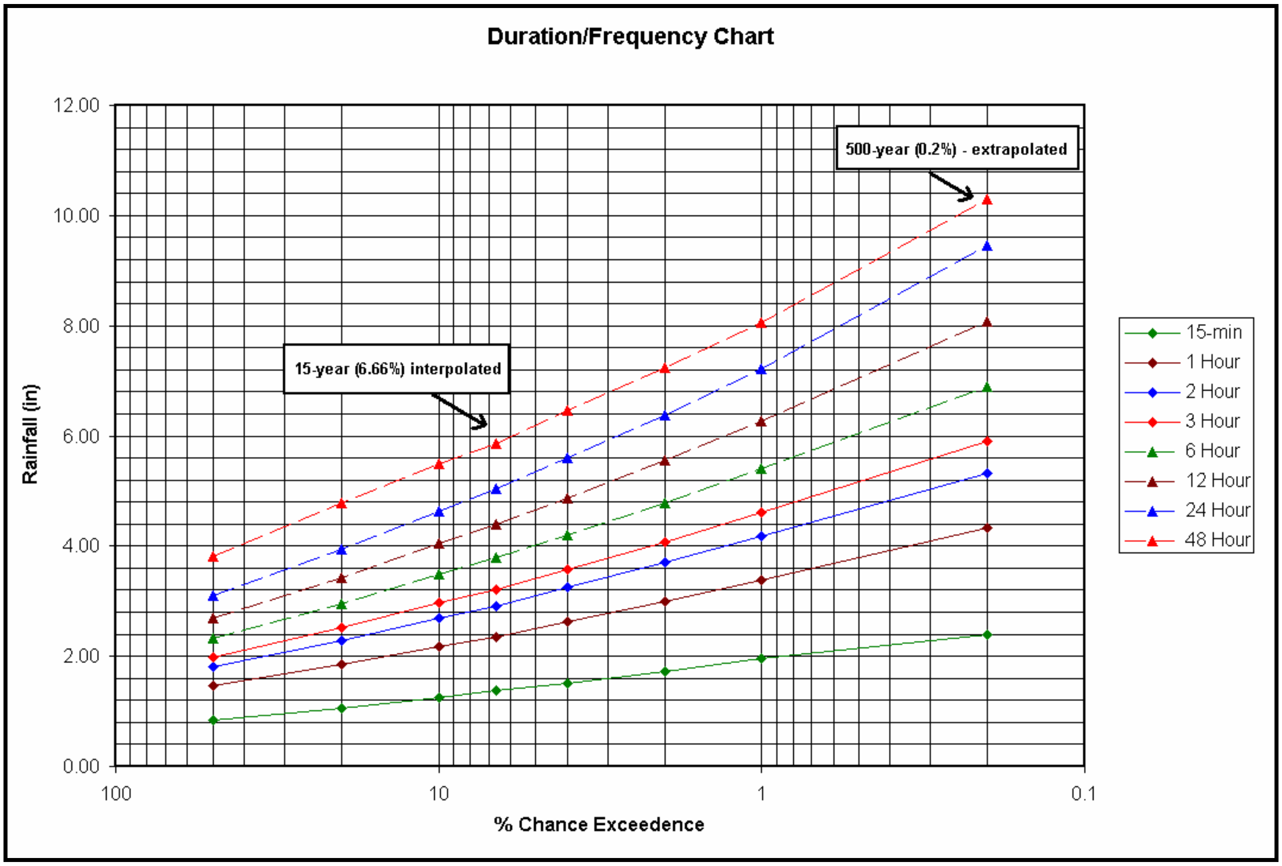

Figure 7.2.5 – Interpolation and Extrapolation of Rainfall Frequencies

7.2.3 Control Specifications Data

The HEC-HMS hydrologic model time parameters for each simulation are contained in the Control Specifications files. The required inputs are the start time, end time, and the calculation time step. The start time for each calibration storm was chosen as an hour or so just before any precipitation was reported from the rainfall gages. The end time was arbitrarily set to 5 days after the end of the rainfall records for each particular storm. This would allow all remaining runoff to completely leave the system, and return to only baseflow. After running each storm, the end time of the simulation could be adjusted to a suitable time, based on inspection of the outflow hydrographs. For the hypothetical storms, an arbitrary start time was selected, because there would be no actual rainfall or streamflow data to accompany the storm simulation. The end time was chosen by the same methods that were used for the calibration storms.

The calculation time step was chosen to be 15 minutes for all model runs performed with HMS. A larger time step would not have correctly captured the peak flow for the smaller Subbasins in the model, while a smaller time step would have produced a high volume of unnecessary data that didn't add to the accuracy of the model. The 15-minute time step was chosen based on previous experience with the program, as well as the particular layout of Subbasins in the Dardenne Creek model.

7.2.4 HMS Model Calibration

A key step in the development of the HEC-HMS hydrologic model was the model calibration. Given the variability of the different hydrologic parameters that are entered into the model, it is important to verify the accuracy of the model with actual known storm events. When all of the input data parameters were computed or estimated, the rainfall from the known storm events could be used in a hydrologic simulation. Due to the limited availability of recorded streamflow data, the calibration of the hydrologic model could only utilize data from two points in the model.

As discussed in **Section 6.5**, the two streamflow gages are located at Highway K in O'Fallon, and Old Town St. Peters near Highway C. These two streamflow gages have 15-minute discharge readings available from late 1999 to the present. Five distinct calibration storms were analyzed, and they took place in the following months: May 2000, June 2001, June 2002, November 2003, and January 2005. These storms were selected for their intensity and the ability to isolate a single storm event in the stream records. **Appendix A5** contains all the streamflow records from both stream gages, for all 5 storm events.

Unfortunately, there were limitations to using data from all of these storms. The January 2005 storm had the highest peak flow ever recorded by the gages, but it occurred in winter, and the frozen, saturated ground may have contributed to abnormally high discharge values in the stream. Therefore, the other calibration storms were determined to be more representative of the watershed response to rainfall. Also, in some cases, multiple peaks were observed in the gage data. In those cases, it was more difficult to get the computed hydrograph to match the observed hydrograph.

Small modifications were made to the SCS Loss Rate and Clark Transform parameters in order to match the observed data. The final model parameters were determined to be the most accurate when the model results most closely matched the observed hydrographs, for as many events as possible. **Figure 7.2.4** below shows the calibration graph at the O'Fallon gage location for the June 2002 storm. The calibration graphs for the two historical storm events with the best correlation are shown in **Appendix B8**. The January 2005 graphs are also shown, to show the abnormality that can occur for a specific event.

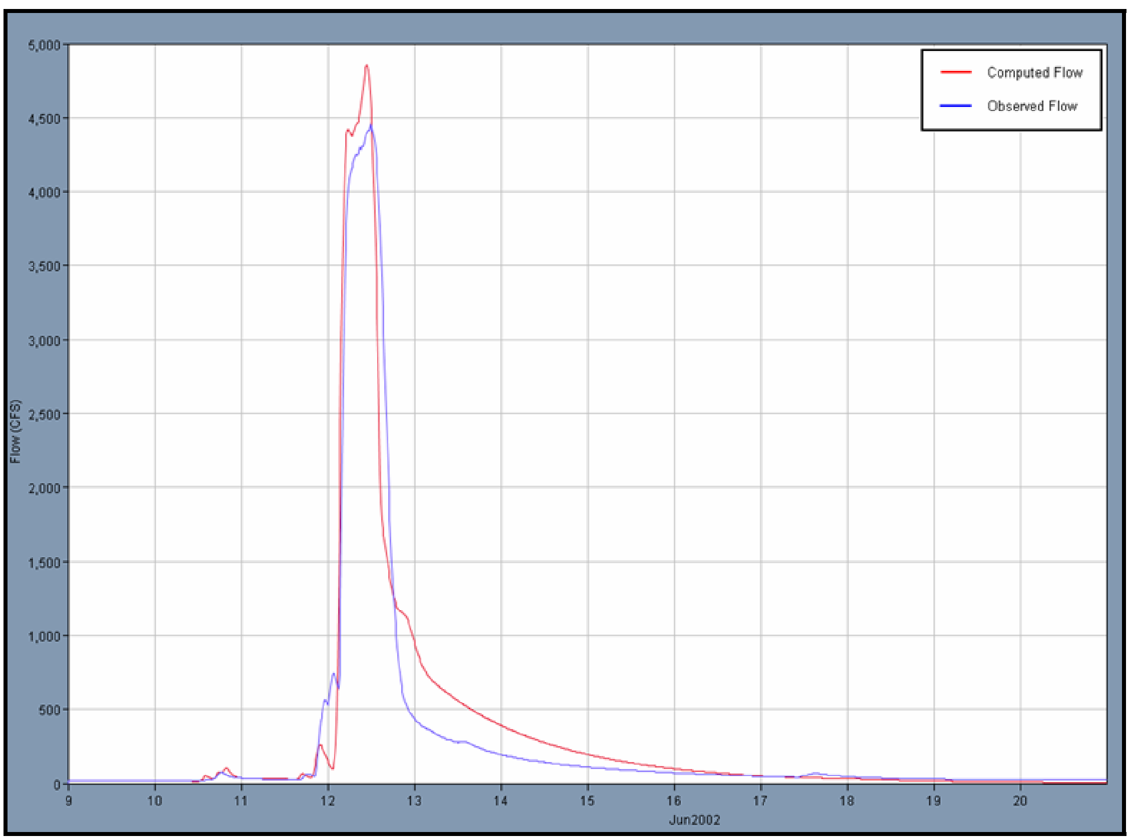

Figure 7.2.4 – Calibration Plot at O'Fallon Gage for June 2002 Storm

7.2.5 Base Condition

After the HEC-HMS model was calibrated to the actual storm events, the eight frequency storms could be analyzed. The rainfall for the hypothetical storm events was described above, in **Section 7.2.2**. Because the output from the base condition modeling was representing a hypothetical storm event, there was no basis for comparison to check the results. In any case, the output from the model was reviewed for any major errors. An abnormal spike in the calculated peak flow would be one example of such an error. The HMS output for the base condition is presented in **Appendix B9**. It is important to note that the base condition model represents the watershed conditions across the entire time frame that this study took place. As discussed in **Section 6**, the data used in the study ranged from 2004 to 2006, so there is not a single point in time that can be called the existing condition. For that reason, the term "Base Condition" was used instead.

Other methods of viewing the new model results were attempted. For a frame of reference, the peak flows from the base condition model were compared to the peak flows from the St. Charles County Flood Insurance Study. However, it was important to remember that many factors made it an uneven comparison. The reasons why the results are not exactly comparable are as follows: 1) The FIS peak flows were calculated with individual stream models, not one detailed large hydrologic model for the entire watershed. 2) The storm duration can affect the peak flow calculation, and smaller streams may have been studied with different storm durations for the FIS. 3) Some peak flows from the FIS may have been calculated with regional regression equations instead of detailed hydrologic modeling methods. 4) Some peak flows from the FIS are only calculated at one point on a tributary stream, and all of the new Dardenne Creek model streams have more than one flow calculation point. 5) Widespread urbanization can have a large effect on the new calculation of peak flows.

For the reasons listed above, the detailed comparison of peak flows from this study to the original FIS values was not included in this report. It should be noted that a comparison of new and old peak flow calculations was not called for in the original project scope. For a more meaningful comparison, the HEC-RAS results were used, showing the difference in the water surface profiles as calculated versus the FEMA floodplain limits. This comparison will be discussed in detail in **Section 9.1**, which is part of the overall project summary.

7.2.6 Forecasted Condition

This section of the report describes the forecasted condition modeling, for each city and unincorporated area within the Dardenne Creek watershed in St. Charles County. The forecasted conditions were developed through discussions and feedback from City and County staff to include approved or anticipated development in the near future. Since each city and county office has their own time frame for projected land use and development, a single date for forecasted conditions could not be chosen. The dates range from about 2010 to 2015.

The forecasted conditions for each agency are listed by project or area name, and a description is given for the changes that will be made to the watershed characteristics and/or stream geometry. The abbreviations “US” and “DS” indicate whether the changes will be applied to the upstream or downstream portions of the basin. See **Appendix B10** and **Appendix B11** for a tabular listing of all modifications to watershed parameters for the forecasted conditions.

Cottleville:

Existing and Future Land Use maps downloaded at www.cityofcottleville.com.

1. Increase in Commercial land use
    a. Along proposed Page Avenue extension, about 0.25 square miles
    b. Along Mid Rivers Drive and Ohmes Road, about 0.2 square miles
2. Agricultural areas converted to residential / commercial, with 20% open space
3. Portions zoned for low density residential become medium density residential

Overall changes to watershed characteristics (Cottleville):

a. Increase SCS Curve Numbers (CN) by 3, except near Dardenne (park space)
b. Increase impervious area 5%, unless in fully developed areas
c. Decrease Times of Concentration by 10%.

Dardenne Prairie:

1. Barat Haven development, 110 acres residential, 90 acres of park space.
2. Planned parks and trail space, 87 acres, south of Dardenne, East of Henning
3. Other minor developments with negligible effects to the watershed.

Overall changes to watershed characteristics (Dardenne Prairie):

a. Increase SCS Curve Numbers by 1 for Trib 13, Trib 15 and Old Dardenne
b. Increase impervious area 2%, unless they in fully developed areas
c. Decrease Times of Concentration by 5%

O'Fallon:

Viewed Land Use plans on Internet at http://www.ofallon.mo.us/, obtained a list of planned developments.

1. 80 acres of commercial developments; largest individual sites:
    a. 17.8 acres near Highway K and Technology Drive
    b. 14.6 acres near Highway 40 and Corporate Centre Drive
    c. 10 acres on Highway K near Dardenne Creek
2. 60 acres of residential lots; 55 acres on Diehr Road, off Highway DD
3. 17.9-acre public development; school expansion on Waterford Crossing Drive
4. Highway 40 Bridge over Dardenne, new lanes, 40' width, 2' higher bridge

<u>Overall changes to watershed characteristics (O'Fallon)</u>

a. Increase SCS CN's by 2 for part of Dardenne, Schote, Crooked, and T-17
b. Increase impervious area by 4% for same areas
c. Decrease Times of Concentration by 8% for same areas
d. Highway 40 Bridge over Dardenne; add extra lane width, deck 2' higher

St. Charles City:

1. Upstream of Mississippi Floodplain, less than 5% remains to be developed
2. Small industrial areas near Boschert and Cole Creeks, minor effects on flows

<u>Overall changes to watershed characteristics (St. Charles City)</u>:

a. Increase SCS Curve Numbers by about 1, Boschert (DS) and Cole (DS)
b. Increase impervious area 5% for same areas
c. Decrease Times of Concentration by about 5% for same areas

St. Peters:

Existing and Future Land Use maps downloaded from Internet, at http://www.stpetersmo.net/.

1. Most vacant space becomes residential, industrial, commercial, or mixed use.
2. Open space remaining in golf courses, and parks along upper Spencer Creek
3. Ohmes Farms – 210-acre residential site off Ohmes Road, Tribs 1 and 2 (US)
4. Lakeside 370 – commercial and recreational use (Spencer / Sandfort Creek)

<u>Overall changes to watershed characteristics (St. Peters)</u>:

a. Increase SCS CN's by 2 for DS of Spencer and Sandfort, US of Trib 1+2
b. Increase impervious area 5%, same area as item #1.
c. Decrease Time of Concentration by about 10%.
d. HEC-RAS model changes for Dardenne Creek floodplain fill near Ohmes Rd.

St. Charles County:

Viewed land use on Internet at http://www.saintcharlescounty.org/; obtained a list of all planned developments.

1. Lower Dardenne is already covered with city data, county info not needed.
2. Conditions changed in Upper Dardenne, residential sites from 3 to 168 acres.
3. Basins: Cunningham, Oday, Kraut, Little Dardenne, Trib 17, and Dardenne.

Overall changes to watershed characteristics (St. Charles):

a. Increase SCS CN's by 2-3 for Upper Dardenne Basins listed above

b. Increase impervious area 5%, for the same areas

c. Decrease Time of Concentration by 10%, for the same areas

Final Notes on Forecasted Condition Modeling:

All eight frequency storms were analyzed for the forecasted conditions. A new basin model file was created, and all of the watershed characteristics were changed as listed above. The same storm duration and time step were used, to stay consistent with the base condition model. The results from the forecasted conditions model are presented in **Appendix B12**.

In general, the peak flows with the largest increase when compared to the base condition occurred in the 2, 5, and 10-year events. In terms of a percent increase, the less frequent events (100 and 500-year) experienced a smaller increase. This result was to be expected, because of the operation of detention basins in newly developed areas. Experience shows that detention basins can actually increase the magnitude of some lower magnitude storms, while performing more effectively on the higher magnitude events. The best method of comparison from the base condition to the forecasted condition will be the flooded area maps resulting from the analysis. The overall results of the forecasted condition modeling and the comparison to base condition will be discussed in more detail in **Section 9.2**.

8. Hydraulic Modeling Methodology

Similar to the HEC-HMS model methodology, the development of the HEC-RAS model can be broken into two main tasks: 1) The model creation using the GeoRAS extension of the ArcView program, and 2) The completion of the HEC-RAS model by modifying hydraulic parameters and adding other features to the stream geometry, such as bridges and culverts. The following sections describe the methods for completing these tasks, along with the displaying of results.

8.1 Model Creation using HEC-GeoRAS / Arc View Software

The main capability of the HEC-GeoRAS extension is the ease of transferring terrain data from GIS format into cross section geometry for use in the HEC-RAS hydraulic analysis program. The necessary input data for this process is created with the ArcView program. The terrain data in this procedure takes the form of a Triangular Irregular Network, or TIN. The other main input is the location of cross sections, which is generated by the program user. This section will explore the GeoRAS process in detail, and examples of the required procedures will be displayed.

The first step in creating HEC-RAS data with GeoRAS is developing the TIN. A TIN is another method of displaying terrain data and using the data for various computations. The TIN is a three-dimensional surface made up of millions of small triangles containing elevation data for each vertex of the triangles. The advantage of using the TIN versus a Digital Elevation Model (or DEM) is the ability to represent irregular data sets. While a DEM is limited to equal spaced squares in a grid, the TIN can contain as many elements as necessary to accurately portray the data. The TIN was produced directly from the points and breaklines from the mapping contract, so there is virtually no loss of accuracy when making the conversion to TIN data. Because the flooded area maps are one of the most important outputs from the watershed study, the source for HEC-RAS geometry is appropriately based on the TIN data, rather than a DEM. A sample of the TIN data can be seen below in **Figure 8.1**. As before, the TIN sample covers the same general area as the samples for the terrain model and DEM (**Figure 6.1.1** and **Figure 7.1)**. Note that the surface is much more well-defined by the TIN as opposed to the DEM. The red and blue lines in the image will be explained in the subsequent paragraph.

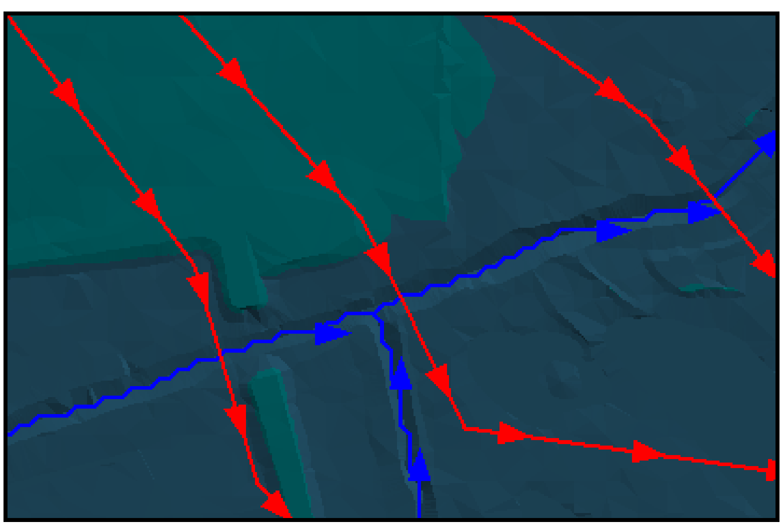

Figure 8.1 – Sample of Triangular Irregular Network (TIN) Data

The second step in the GeoRAS procedure is the creation of actual HEC-RAS geometry from the TIN data, which is accomplished as follows. The stream centerline was defined to be the same as the river reach definition from the GeoHMS process. The centerline feature contains both Dardenne Creek and all of its tributaries, and it can be seen as an overlay on the TIN sample as a blue line. The centerline of Baltic Creek is visible in the bottom center portion of the sample area. Next, the desired cross section locations are drawn in the ArcView GIS program. The lines are known as cross section cut lines, and they are displayed as red lines in the above sample. The cross section cut lines are drawn perpendicular to the stream centerline, and from left to right looking downstream. The ArcView plot showing the section locations for GeoRAS is shown in **Appendix C1**.

This is the same basic procedure that would be used if cross sections were created from a paper copy of a USGS quad map. The major difference in the process is that a single calculation with GeoRAS can create the station and elevation pairs that define each section in HEC-RAS. The added bonus is that the GeoRAS extension also produces a RAS schematic that is geo-referenced. This can greatly help the user's ability to visualize the model as a whole. The one limitation of the GeoRAS method is the inability to achieve an accurate definition of the channel, or streambed geometry. Since the terrain data was developed from aerial photography, the water in the stream channel prevents a clear view of the stream bed. For this reason, the GeoRAS cross section geometry was supplemented with other data for the stream channels. This process will be described in **Section 8.2.1** below.

8.2 Hydraulic Modeling using HEC-RAS Software

After the GeoRAS program creates the stream geometry from the terrain data, additional physical stream features and other supporting data are added to the hydraulic model, within the HEC-RAS program. Most of the additional data is added to the RAS geometry file, but some additional input is required for the RAS steady flow data file. Once all the data was gathered, the base conditions and forecasted conditions could be modeled. The remainder of work on the HEC-RAS model is discussed in the following sections.

8.2.1 Geometric Data

The newly developed hydraulic model for Dardenne Creek measured just over 40 miles in length. A total of 20 first-order tributaries and 10 second-order tributaries were also included in the single RAS geometry file. The geometry file from the GeoRAS export file contained only cross section data, and did not include any other structures such as bridges and culverts. These details were added manually, along with the other necessary variables to complete the analysis. When the final modifications were made to the geometry, the file contained 1,129 cross sections, 57 bridges, 84 culverts, 36 lateral structures (levees), and 3 inline structures (dams and low-water bridges). The geometry modifications are discussed here.

Cross Section Modifications:

As discussed in **Section 8.1** above, the channel definition was the key component missing from some of the GeoRAS cross sections. Since every creek had an alternative source for channel data, the HEC-RAS geographical cross section editor was used to import the best data available to define the channel. In most cases, cross sections from the field survey contract were the best available representation of the channel. In locations where field surveys were unavailable, the previous HEC-2 model files were utilized as the best available channel section data. **Figure 8.2.1** below shows an example of a cross section with its supplemental channel data. The section is from Dardenne Creek near Baltic Creek, and the lack of detailed channel data in the GIS section was ameliorated by using field survey information.

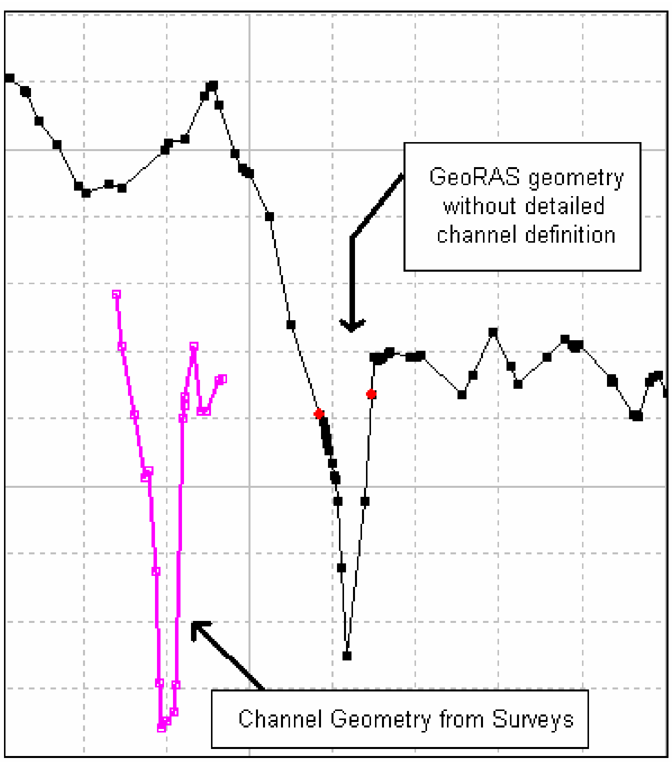

Figure 8.2.1 – Improvements to GIS Channel Geometry with Field Surveys

After the actual ground surface was represented for all locations in the HEC-RAS model, fine tuning of the sections took place. Levees and ineffective flow areas were sometimes needed to confine the flow calculations to the correct locations in each cross section. When a levee is defined at a point in the section, no flow can be carried in the area outside of that point (away from the channel) until the levee elevation is overtopped. On the other hand, while water can flow in an area defined with the ineffective flow designation, the section is not able to actively convey water there. In other words, the water can exist as storage, but is not included in the calculation of the conveyance of the section.

The levee option was used frequently, particularly in the area of the Mississippi Floodplain, where levees confine the lower flow events to the channels of Dardenne Creek, Spencer Creek, Sandfort Creek, Cole Creek, and Boschert Creek. The ineffective flow area option is used most often at bridges, when the overbank flow slows to a crawl as it reaches the actual roadway, which confines the flow to the channel. **Figure 8.2.2** shows the difference between levees and ineffective flow graphically, using a section from Spencer Creek as an example.

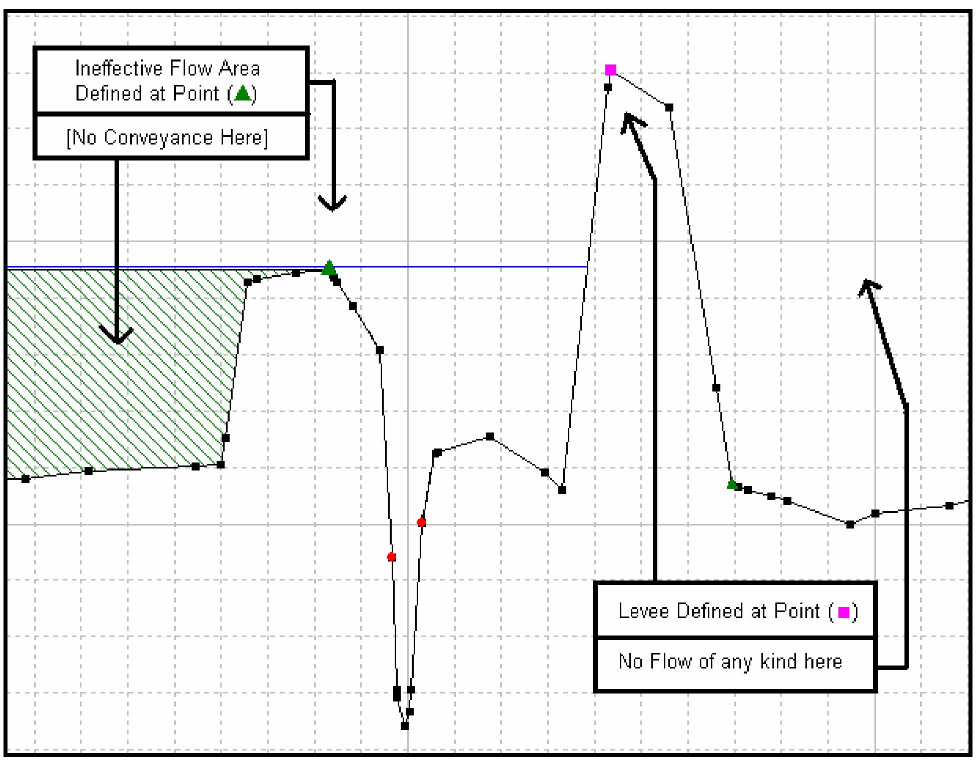

Figure 8.2.2 – Levees and Ineffective Flow Areas in HEC-RAS

The other main hydraulic variables that are involved in the calculation of water surface profiles are the Manning's N roughness coefficient and the Contraction and Expansion Coefficients. Manning's N values are the main variables used to calibrate the hydraulic model, and they are estimated from visual inspection of the creek channel and overbank areas. The rougher the terrain, the higher the N value, which results in a lesser ability of the section to carry water efficiently. Notes from site visits, photographs, and the helicopter videos all contributed to the estimation of Manning's N values. In very remote portions of the streams that could not be reached by field visits, previous model studies or aerial photos were consulted to make n-value estimates. The ranges of Manning's N values that were used for all streams are listed in **Appendix C2**. The typical values used for Dardenne Creek and a few tributaries are shown here in **Table 8.2.1**.

Table 8.2.1 – Typical Manning's Roughness Coefficients

Creek:	**Channel N Range**:	**Overbank N Range**:
Dardenne Creek	0.04 - 0.055	0.06 - 0.07
Boschert Creek	0.035 - 0.05	0.055 - 0.075
Schote Creek	0.045 - 0.05	0.06 - 0.07
Oday Branch	0.04 - 0.05	0.055 - 0.07

The Contraction and Expansion Coefficients do not have as much of an effect over the course of the model as Manning's N, but are important for calculations near bridges and culverts. The typical values for Contraction and Expansion coefficients are 0.1 and 0.3, respectively. For the two sections immediately upstream and downstream of each bridge and culvert in the model, values of 0.3 and 0.5 were used instead, as dictated by previous Corps experience with the HEC-RAS program.

Bridge and Culvert Data:

The modeling of bridges and culverts was by far the most time consuming portion of the RAS geometric data. As stated earlier, 57 bridges and 84 culverts were found to cross Dardenne Creek and its tributaries. In some rare cases, small crossings were determined to have negligible effects on the flood stages of the storms, and were therefore not modeled. A prime example of this is a low water crossing of a cart path for a golf course, of which there are many in the system. If other crossings are found at a later time, that do not exist in the Corps'

Dardenne Creek Model, it is likely that the bridge or culvert was constructed after the data gathering for that area of the study took place.

For each bridge or culvert in the model, the following information was gathered by the field survey contract, from the inspection of as-built plans, or from site visits made by the Corps: bridge deck or roadway width (in the direction of the flow of the creek), bridge opening width and height, bridge deck thickness, bridge opening roughness, culvert size and length, culvert material type, headwall type and size, wingwall type and the wingwall's angle from parallel. The Bridge and Culvert editor of HEC-RAS is the method of input for this data. The main data entry window for defining the bridge structure is the deck/roadway editor. A station/elevation pair defines the roadway surface, known as the high chord, which will determine which portion of the cross section's flow will be blocked by the roadway embankment. For a bridge, a low chord is defined as the underside of the bridge deck, meaning another station/elevation pair defines the open area where the channel flow can pass. For a culvert, no low chord is defined. Instead, the culvert editor is used to define each barrel or concrete box under the road. In some cases, flow blockages were entered into the culvert data, in locations where years of sedimentation have deposited earthen material (see **Figure 8.2.3** for one such example of this, from Sandfort Creek at Highway 370).

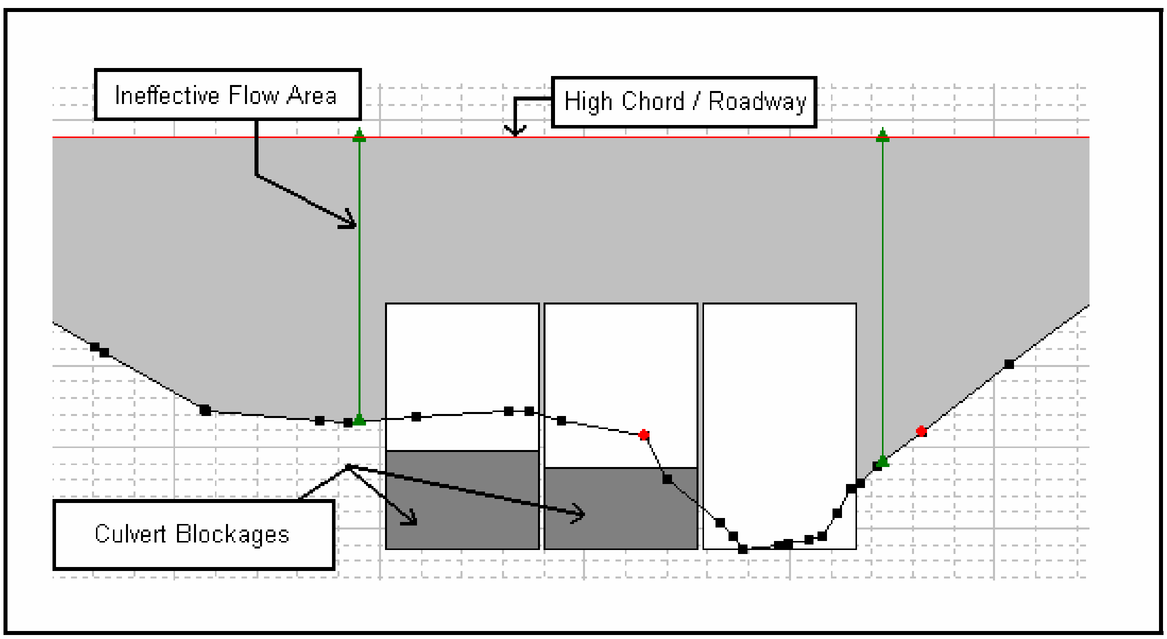

Figure 8.2.3 – Culvert Blockage on Sandfort Creek at Highway 370

Lateral Structures:

In the area of the Mississippi Floodplain, Dardenne Creek and four of its tributaries have levees to protect the overbank areas from the Mississippi backwater. Spencer, Sandfort, Cole, and Boschert Creeks are the tributaries that also have levees outside of the channel. This presents an interesting challenge for the hydraulic modeling of the creeks. The flat, open area of the floodplain extends out hundreds or even thousands of feet away from the levee-lined creek channels. Any flow spilling over the levees can spread out fill the floodplain, but will not re-enter the creek during the storm event. Instead, gravity drains allow the floodwaters to return to the channel after the peak of the storm has cleared out of the channel.

This is a difficult scenario to accurately analyze with a steady flow hydraulic model. Since this watershed study is only concerned with the water surface profiles for peak flows, the gravity drain flow is not a factor to consider. However, any flow that spills over the levees and does not return will result in a lower peak flow continuing downstream in the channel. One method of calculating the reduced flow is to represent each levee as a lateral structure in HEC-RAS, which uses weir equations to calculate the amount of flow leaving the system. The lateral structure function was used to define a total of 36 levees on the five creeks. With this added levee geometry, an attempt was made to optimize the flow remaining in the channel with the flow leaving over the levee. A solution is usually found through an iterative calculation, but the procedure did not converge to a solution in this case. Unfortunately, at the time of this study, there is a limitation in the ability of HEC-RAS to perform such a calculation for several levees at the same time in a steady flow analysis. Therefore, the flow leaving the channel by way of the levees was accounted for with another method, which is described here.

As mentioned in **Section 7.2.1**, in the portion covering Modified Puls Routing data, the HEC-RAS model geometry was used to define a storage-discharge relationship for every reach of the creeks. For the five creeks in the Mississippi Floodplain, the large floodplain area offers vast amounts of storage, provided that the calculated water surface is higher than the levee elevation. When the lateral structures were added to the model, the extra storage was considered to permanently leave the system. So, the Modified Puls method of routing will account for the flow that can be stored outside the channel, which results in a decreased peak flow and lower river stages.

Although the levees did not fully function as desired, they were left in place in the model, with the flow optimization calculation option turned off. In this fashion, they will not adversely affect the computed water surface profiles, but they can be used in later modeling efforts, when the steady flow calculations in the RAS program are improved. Alternatively, the levees can be studied with an unsteady flow analysis at a later time, which unfortunately falls outside the scope of this study.

Inline Structures:

In order to calculate meaningful water surface profiles both upstream and downstream of the two reservoirs in the system, inline structures had to be added to the model at the location of the dams for Lake 33 and Lake 35. The placement of the inline structure results in the backing up of water behind the dam, and the resulting water surface looks like the example shown here in **Figure 8.2.4**. The inline structure in RAS ensures that the correct flooded area is calculated for the entire lake surface upstream of the dam.

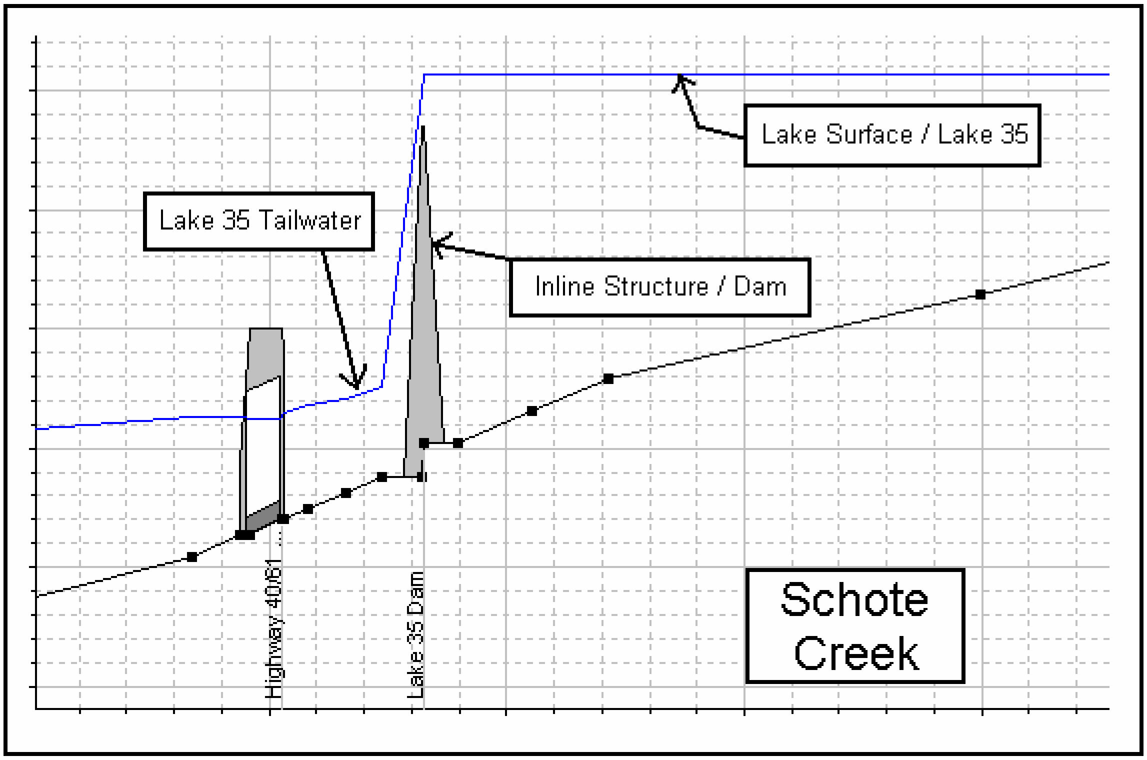

Figure 8.2.4 – Inline Structure for Lake 35 in HEC-RAS

The required data input for an inline structure is not as detailed as that for a bridge or culvert. The main inputs required for inline structures are the top elevation of the dam, and the length and depth of any overflow points, such as an emergency spillway. Therefore, the same information that was used to develop the elevation-storage-discharge curve for HEC-HMS was sufficient to define the inline structure with HEC-RAS. **Table 8.2.2** below shows the pertinent dam data for Lake 33 and Lake 35.

Table 8.2.2 – HEC-RAS Inline Structure Data for Lake 33 and Lake 35

Dam Site:	Crest Elev:	Overflow Elev:	Overflow Length:
Lake 33	520.0	515.0	70 feet
Lake 33*	520.0	516.5*	100 feet*
Lake 35	565.7	557.0	130 feet

(*) Note: Lake 33 was modeled with a second overflow section, where the terrain allows water backed up at the lake to overflow to Dardenne Creek.

Interpolated Cross Sections:

The final additions to the HEC-RAS geometry file were the interpolated cross sections. When the base condition was modeled, as described in **Section 8.2.4** below, some additional sections were required to smooth the profiles. The addition of cross sections does not alter the known geometry that is already in the system. Instead, it offers the steady flow calculation extra locations to complete the calculations. This is especially helpful for the areas near bridges, and in areas where the backwater from a structure transitions back to normal flow conditions. For interpolated sections in the geometry file, the cross section description “Interpolated for Profile Smoothing” has been added.

8.2.2 Steady Flow Data

A direct transfer of peak flow data from HEC-HMS to HEC-RAS is not quite possible with the current version of the programs. However, the output data from HEC-HMS is automatically placed in a data file with the HEC-DSS format. Then, an import option is available in HEC-RAS, by specifying the source of the data in the DSS database. This process was repeated to set up the peak flow values for every flow change location for all HEC-RAS simulation runs. At a minimum, the flow change locations are required at the most upstream point of every creek. Because the HEC-HMS model contained a very detailed breakdown of the watersheds, there were many more known flow points available to use.

Therefore, a new flow change location was specified for each HMS reach in the stream network. **Appendix C3** and **Appendix C4** contain the lists of flow change locations and the peak flows for the hypothetical events. **Appendix C3** contains the flows for the base conditions, and **Appendix C4** contains the flows for the forecasted conditions.

In addition to the actual flow values, the steady flow file contains other information required to complete the analysis. In a steady flow analysis with subcritical flow, a downstream boundary condition must be defined. The boundary condition tells the HEC-RAS program how to begin the standard step backwater calculations at the most downstream point in the model. In the Dardenne Creek model, the mouth of Dardenne Creek at the Mississippi River is the most downstream point. Therefore, the Mississippi River elevation represents the starting point for any simulation.

When the hypothetical frequency storms were modeled, a conservative estimate was used for the starting water surface. For each frequency event studied, the corresponding flood elevation of the same frequency on the Mississippi River was used. Using the Corps' river navigation maps as a guide, the mouth of Dardenne Creek is located at river mile 227.3 on the Mississippi River. At that location, the elevation of the 100-year flood for the Mississippi River is 441.4 feet. The known water surface elevations for every storm frequency are shown here in **Table 8.2.3**. The Mississippi River Flood Frequency profiles were obtained from the Corps of Engineers Water Control Office. That river profile data can also be conveniently accessed through the web at the following location: http://www2.mvr.usace.army.mil/flow_freq/flow_freq.cfm.

Table 8.2.3 – Starting Flood Elevations from Mississippi River Backwater

Event:	**Elevation:**
2-Year	429.0 feet
5-Year	433.2 feet
10-Year	434.6 feet
15-Year	435.7 feet
25-Year	437.4 feet
50-Year	439.5 feet
100-Year	441.4 feet
500-Year	444.3 feet

For the calibration storms, a normal depth calculation was assumed, because the Mississippi River was not experiencing a flood event at the time. A normal depth boundary condition is defined by specifying an energy grade slope at the downstream end of the reach. The slope of the channel invert was used as an approximation, but the value was modified as necessary during the calibration process. The final accepted value for the downstream energy slope was found to be 0.00005. This is a very low value for a slope, but it is consistent with the lower portion of a stream in the floodplain of a large river system like the Mississippi. It is also important to note that the downstream boundary for every tributary stream in the system is the elevation of Dardenne Creek at the mouth of the tributary. The RAS model conveniently calculates these stages before moving on to the tributaries, which is a significant benefit gained from operating a comprehensive model such as this one.

The remaining data entry parameters for the steady flow data file are optional. The only other data entered for the Dardenne Creek study was the observed water surface data. This option was used for the calibration storms only, because the stream gage data and observed high water marks only applied for the simulation of historical events. As discussed in **Section 6.5**, the high water marks for the January 2005 storm are listed in **Appendix A6**.

8.2.3 HEC-RAS Model Calibration

The calibration of the HEC-RAS hydraulic model involves a comparison of computed flood elevations to observed data. As stated in the scope of work document, in **Appendix D1**, the calibration of the models "will only be done on the mainstem of Dardenne Creek." The primary reason for this is the fact that the only recording stream gages are the O'Fallon and St. Peters gages on Dardenne Creek. Historical evidence or eyewitness accounts would be the only methods for obtaining reliable flood elevation data on tributaries.

The first step for calibrating the model for Dardenne Creek was deciding which storm events and peak stage information could be used to calibrate the model. The available stream gage data runs from late 1999 to the present. However, the observed high water marks only applied to the storm of January 2005. Since it was important to calibrate as many locations as possible, the January 2005 storm would definitely be used. It was also decided to use the November 2003 storm, because it was the storm with the best hydrograph correlation during the

HEC-HMS model calibration. To round out the calibration process, all three additional storms from the HEC-HMS modeling effort were also computed. It is important to note that for all storms besides the January 2005 storm event, only the two USGS gage locations could be used for the comparison.

Since the high water marks offered many points for calibration, the January 2005 storm was used for the first calibration runs. The Manning's N values, and some bridge and culvert details were modified, in an effort to more closely match the observed elevations. It was also at this point that the downstream boundary condition was finalized at a slope of 0.00005. The HEC-RAS program was used to plot the model results with the observed elevations. The Manning's N values were modified a final time to match the stages as well as could possibly be done, within a reasonable range for the parameters. The profile plot from the final calibration run is shown in **Figure 8.2.5** below.

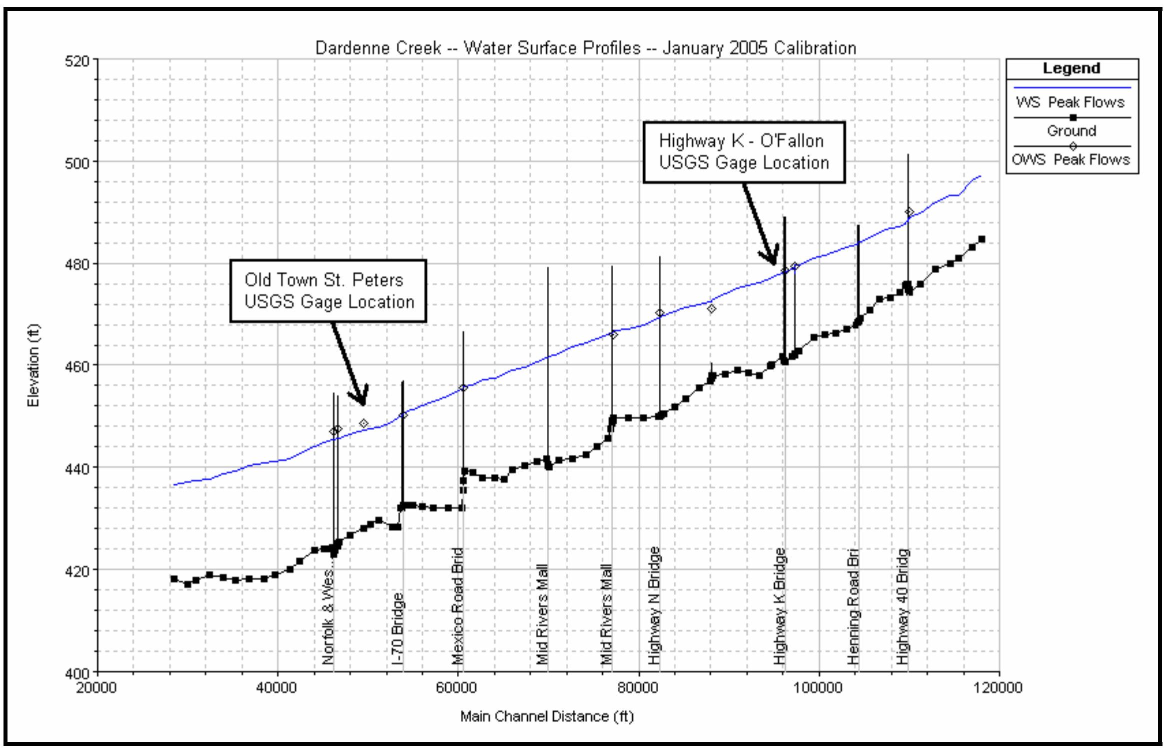

Figure 8.2.5 – HEC-RAS Profile Plot for January 2005 Calibration Storm

In this profile plot, the computed water surface is shown as a blue line, and the small diamond shaped symbols are the observed peak stages from the USGS gage and high water marks. Some minor differences were found between the computed and observed stages, but matching the observed data exactly would have required changing the Manning's N values beyond the reasonable range for the parameters for a stream of this type.

After the simulation of the 2005 storm was completed, the other calibration storms were also run in HEC-RAS, to double check the model accuracy. The results of the final calibration runs are shown here in **Table 8.2.4**. The column "W.S. Elev" shows the value for the elevations computed by the HEC-RAS program. "Obs WS" indicates the actual measured elevation, or observed data. A calculation was made to show the overall correlation of the computed data to the observed data. The average change between the two values was about 0.2 feet. The average of the absolute value of the change was about 0.9 feet.

Table 8.2.4 – Overall Results of HEC-RAS Calibration

Calibration Storm	Gage Location	W.S. Elev (ft)	Obs WS (ft)	Change from OBS (ft)	Absolute Change (ft)
2000-May	O'Fallon - Highway K	478.71	478.7	0.01	0.01
2000-May	Old Town St. Peters	449.13	446.4	2.73	2.73
2001-June	O'Fallon - Highway K	476.47	477.2	-0.73	0.73
2001-June	Old Town St. Peters	446.9	446.2	0.7	0.7
2002-June	O'Fallon - Highway K	479.46	478.2	1.26	1.26
2002-June	Old Town St. Peters	448.22	447.2	1.02	1.02
2003-November	O'Fallon - Highway K	477.15	477.4	-0.25	0.25
2003-November	Old Town St. Peters	446.34	447.1	-0.76	0.76
2005-January	O'Fallon - Highway K	478.2	478.7	-0.5	0.5
2005-January	Old Town St. Peters	447.29	448.6	-1.31	1.31
				0.22	**0.93**
				(AVERAGES)	

Some interpretation of the observed gage data could explain any remaining discrepancy between the computed and observed stages. Note the difference between the observed data from the 2000 and 2005 storms; although the exact same peak stage was reported for the O'Fallon gage for both storms, the St. Peters gage reading was over 2 feet higher for the 2005 storm. This anomaly could indicate that the pattern of rainfall over the watershed caused much higher observed stages than expected at the downstream end of the creek. It is possible that the limited number of rainfall gages could not accurately portray the complex storm pattern for the HEC-HMS simulation. Therefore, the peak flow values entered into HEC-RAS may not have been completely accurate, but they were the best possible representation with the available data.

Other factors could influence the calibration results, such as the recent rainfall prior to each storm. The HEC-HMS model runs an isolated storm event, and assumes an average amount of antecedent moisture (ground saturation that comes from previous rainfall over the watershed). However, it is possible that an isolated portion of the watershed received rainfall in previous days, resulting in a higher peak flow at the lower portion of the stream. Given the variability of these factors affecting the stream hydraulics, the HEC-RAS model was found to be very suitably calibrated, as displayed in **Figure 8.2.5** and **Table 8.2.4** above.

8.2.4 Base Condition

With the hydraulic model calibrated, the hypothetical storms could be run for the base condition, for each of the specified frequencies. The frequency flows for the 2, 5, 10, 15, 25, 50, 100, and 500-year storms, as computed in HEC-HMS, are displayed in **Appendix C3**. As discussed in **Section 8.2.2**, the flow inputs were not the only change required to run the hypothetical storms. The starting water surface elevations, from the Mississippi River profiles, were entered for the downstream end of Dardenne Creek. The same HEC-RAS geometry data file that was used for the calibration storms was also used for the hypothetical storms, so no further modifications had to be made to run the simulation.

The computed water surface profiles were inspected through the output tables and profile plotting capabilities of HEC-RAS. The most difficult aspect of modeling eight different flow profiles is the fact that natural stream geometry may result in computations that appear inconsistent. For example, one would expect that a higher peak flow value will always result in a higher computed water surface, which would prevent any of the eight profile lines from crossing. However, literally dozens of locations experienced the phenomenon of a higher stage resulting from a lower peak flow. These apparent errors are caused by the different methods used to calculate the correct water surface, and the interaction of flow from one section to the next one upstream.

One significant limitation of the HEC-RAS program is that each profile is calculated independently of all other profiles. In other words, the program doesn't know that it is creating these inconsistencies, and it cannot recalculate the water surfaces to ensure that the profiles don't cross. So, the only way to fix the problem is to modify the RAS geometry until the profiles are in order. In most cases, the profiles crossed near bridges, and the bridge modeling approach parameters were changed to correct the profiles. Interpolating extra cross sections was also found to be effective for fixing profiles that were out of order. The profile plot excerpts in **Figure 8.2.6** show examples of the situations where these corrections were necessary.

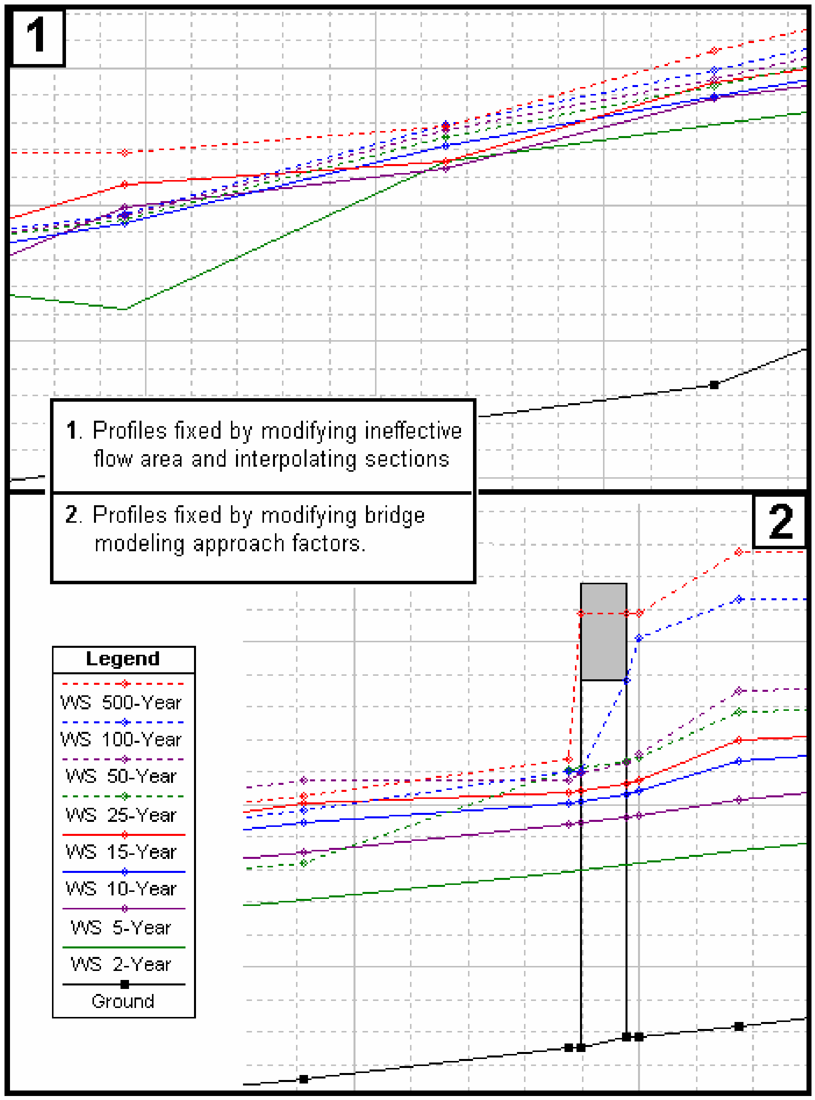

Figure 8.2.6 – Examples of Crossing Profiles in HEC-RAS Output

In other cases, the profiles crossed because a higher flow suddenly increased its velocity and the calculated elevation dropped drastically. The reason this occurs can be explained with the basic hydraulic relationship of Q = V x A. The Peak Flow (Q) is not changing in one particular reach of a stream, so if a higher Velocity (V) is carrying the same flow, then the Flow Area (A) must be smaller, and the water surface must also be lower. Using the ineffective flow area option, the velocity was slowed down for the section, and a higher, more accurate water surface was calculated for the higher flow profile. The ineffective flow area assures that reasonable velocities are carried in the creeks, and also results in a more conservative final model. All instances of crossing flow profiles were corrected for the final model included on the data DVD with this report.

When all of the water surface profiles were found to be accurately computed, the data was printed to output tables, as well as water surface profile plots. **Appendix C5** contains the output tables for all computed water surfaces for the eight frequency storms. The water surface profile plots would be somewhat difficult to present with all eight storm events plotted. Therefore, **Appendix C6** contains a plot of the four profiles that are also used for FEMA Flood Insurance Studies, which are the 10, 50, 100, and 500-year floods. The flooded area maps for the 100-year event were also produced, as described in **Section 8.3** below.

8.2.5 Forecasted Condition

Very few changes were made to the HEC-RAS geometry file to create the forecasted conditions run. The main difference between the base and the forecasted conditions would be accounted for with the flow data input to the model. The HEC-HMS runs for forecasted conditions were added to the HEC-RAS steady flow data file. The frequency flows for the eight hypothetical storm events can be found in **Appendix C4**. The two changes to the RAS geometry that were required are discussed here. All significant observations from the forecasted condition modeling are covered later in **Section 9.2**.

(1) Ohmes Farms modifications:

The Ohmes farms development is located near the mouth of Tributary 1 at Dardenne Creek in St. Peters. A representative from the City of St. Peters provided plans for the proposed changes, and the geometric changes were made to the HEC-RAS model accordingly. Following the proposed development plan, a small portion of the floodplain was filled along the left descending bank of Dardenne Creek, for the embankment of the extension of Sunny Hill Boulevard.

(2) Highway 40/61 Bridge modifications:

At the time of this report, two new lanes for the Highway 40/61 Bridge over Dardenne Creek were under construction. From a field inspection visit, it was noted that the new bridge is about two feet higher than the old one. Allowing a larger opening should not adversely affect the flood stages on Dardenne Creek, but at this time, it is not known whether the remaining bridges will also be raised two feet. Therefore, only the additional bridge width and height for two lanes were added for the forecasted conditions.

8.3 Producing Flooded Area Maps using HEC-GeoRAS / ArcView Software

The final step in displaying the results of the HEC-RAS modeling effort was the production of the flooded area maps. The HEC-RAS program has a simple function to export the water surface elevations from any model run. The export file also contains the geo-referenced cross sections and the stream centerline, if necessary. The procedure to convert the RAS output to useful flooded area maps with GIS is described here.

The required data for plotting flooded area are the HEC-RAS export file and the terrain data in the form of a Triangular Irregular Network (TIN). The same TIN that was used for cutting cross sections will also be used to plot the flooded area. The GeoRAS extension of ArcView is activated, and a new directory is created for the ArcView shapefiles that are produced in this process. The first calculation in GeoRAS creates a polygon shapefile that covers the flooded area based on the portion of each GIS referenced cross section that is inundated. For added detail, a water surface TIN is created based on the intersection of the flooded area polygon with the original terrain surface TIN. The final flooded area is determined by which areas of the water surface TIN are above the ground surface. The flooded areas are then created as a polygon-themed shapefile.

This process is essentially automated in the ArcView program, with the data locations being the only input required by the user. The procedure does have one factor for fine tuning, and that is the rasterization cell size, which is set to as small a value as possible that will still allow for a completion of the calculation. Given the large coverage area of the project, if a value too small was chosen for cell size, the computations would cause the program to lock up, or give an error message. A suitable cell size of 5 feet was used.

When the final flooded area shapefiles were completed, they could be used in any GIS view containing data in the same projection, which is the Missouri East State Plane. For our purposes, the most useful GIS maps for comparison are the current FEMA floodplain maps. The FEMA maps were downloaded from the Internet as a part of the data collection efforts for this project. The GIS program can be used to overlay one or several of the FEMA maps with the flooded area for the newly developed 100-year event. In this way, comparisons can be made to see what changes were computed with the new model. **Appendix C8** contains the flooded area maps showing the new Dardenne model results versus the FEMA floodplain limits.

In order to assess the forecasted conditions, two similar shapefiles from the GeoRAS procedure were compared. The GeoRAS operation for plotting the flooded area was repeated for the 100-year event from the forecasted conditions model. A view window can then be created in ArcView that shows the results of both the base and forecasted conditions for the Corps Dardenne Creek model. Although the entire area can be plotted in a similar fashion as in **Appendix C8**, the difference between the forecasted and base conditions is so minimal in many cases, that a plot of the entire area would not show anything worthwhile. In areas with steep terrain, even a rise in the water surface of one or two feet could not be perceived when viewing a plot at a reasonable scale. For the purposes of this study, only the areas with noticeable differences were identified and plotted. **Appendix C9** shows the few areas where there is a significant difference between the flooded areas for the forecasted condition versus the base condition.

9. Summary of Watershed Modeling Efforts

The HEC-HMS and HEC-RAS models for the Dardenne Watershed were calibrated and used to evaluate base conditions and forecasted conditions. The results were inspected in table and profile format, and flooded area maps were also plotted and compared. The comprehensive nature of the study offered a unique glimpse at how the entire Dardenne Creek system works, with all significant tributaries included in the model. In this final main section of the report, the results will be discussed in detail.

The newly developed base condition model will be compared to the original St. Charles County Flood Insurance Study, with an understanding that the new model results should be somewhat different, considering the changes to the watershed and the differing methods of analysis. The new forecasted conditions model will be compared to the new base condition model, with the 100-year flood elevations being the primary means of comparison. An important note on the application of these models in real world situations is included. Final observations on the performance of the models and any areas of concern are discussed here.

9.1 Comparisons to Current FEMA Flood Insurance Studies

In accordance with the project scope, the final watershed study results for the base conditions were compared to the data from the FEMA Flood Insurance Study. FEMA

Flood Insurance Rate Maps (FIRM) display a plot of the 100-year floodplain, which is a reasonable criterion to make the comparison. However, it is important to note the reasons why the comparison is expected to show that the computed floodplain limits have changed significantly over the past several years.

Changes to terrain and creek geometry are the main contributors to the variation of model results. **Figure 9.1** below shows an example where Highway N was relocated, the floodplain has been filled for a commercial development, and the stream itself has been relocated. In this case, a comparison of the flooded areas from the FEMA to the Corps models does not represent a change in hydrology. There were several such instances of changed geometry throughout the Dardenne Creek watershed. The 100-year flooded area maps, overlaid on the FEMA floodplain limits, are contained in **Appendix C8**.

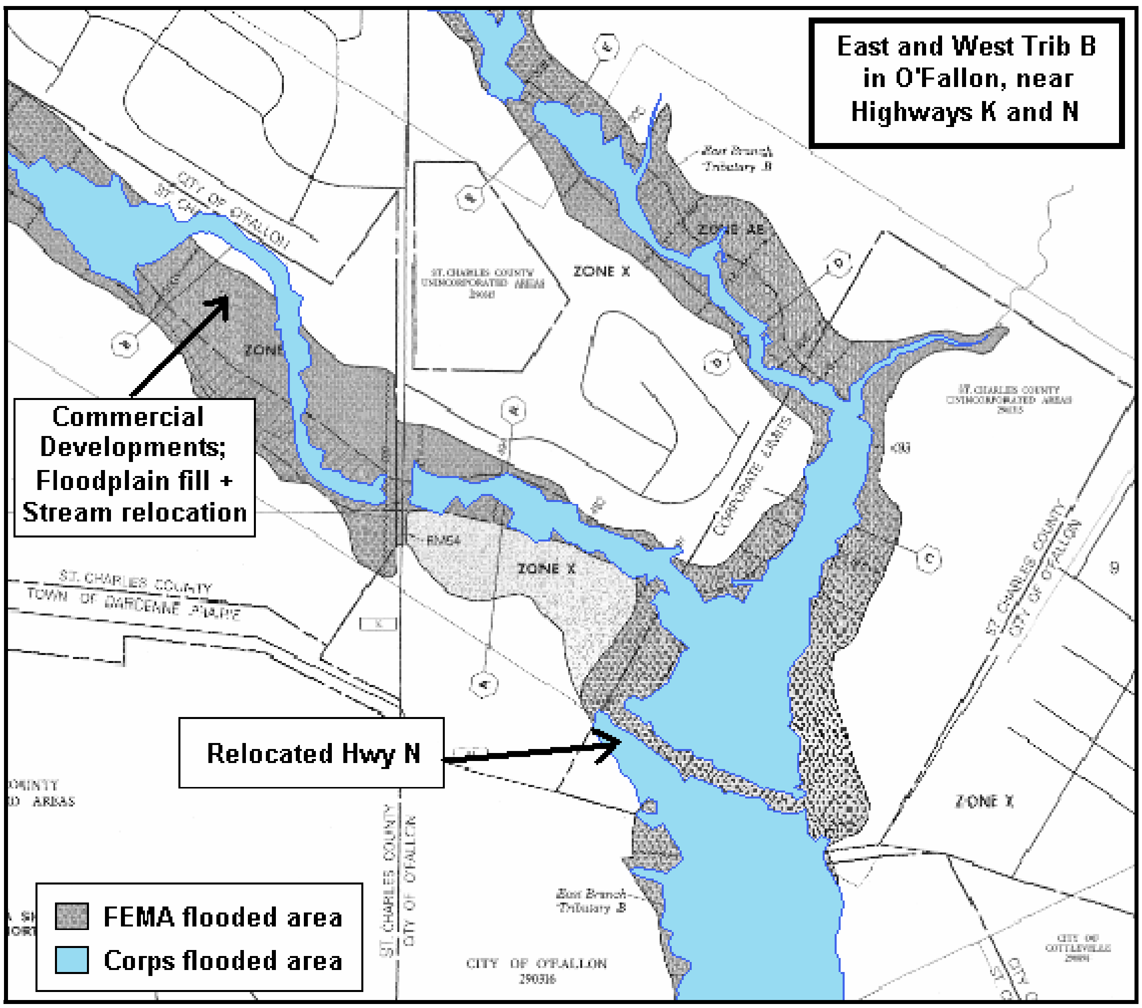

Figure 9.1 – Detail of Flooded Area Comparison

Variation in the analysis methods is another key reason that a discrepancy was expected between the old and new model results. The comprehensive study performed by the Corps considers the river system as a whole, but the FEMA flood maps represent a collection of several individual model results. A change will also be expected based on the method for combining hydrographs, and the way that backwater effects are estimated.

Also, the peak flows will vary from one model to another simply based on the hydrologic parameters chosen, such as the type of loss rate and hydrograph transform methods. Overall, the 100-year flooded area for the new model is actually smaller than the FEMA floodplain limit. This is primarily due to changes in the terrain, as discussed above. In other cases, the newly computed peak flows are significantly lower than those in the original FEMA study. The most likely reason for this occurrence would be the case where the FEMA study used regional regression equations rather than a detailed hydrologic study. The analysis methods for the new Corps study can be considered more advanced, and utilize better terrain data than the FEMA studies in almost every case.

9.2 Forecasted Condition vs. Base Condition

When the two HEC-RAS runs for hypothetical flows were completed, a comparison was made, in order to find out if there would be a significant difference between the base condition and the forecasted flooding conditions. Three main criteria were used to compare the two runs: magnitude of peak flows, computed water surface profiles, and flooded area for the 100-year event. Although eight storm events were run for each condition, it was not feasible to make some of the comparisons for every flood event. This section will discuss the comparisons of peak flow values, water surface elevations, and flooded areas that were made between the base and forecasted conditions.

Peak Flow Comparison:

The peak flows for the eight frequency storms were compared to determine how large an effect the forecasted condition modifications would have. On average, there was an increase in peak flow when comparing the forecasted condition to the base condition, but some locations either stayed roughly the same or even dropped slightly. A drop in the peak flow can be explained by the timing of hydrographs in the system – if one basin had a lower time of concentration applied to it, then the runoff response from that Subbasin might be able to move out of the system earlier, resulting in a lower peak flow in the creek downstream. Another key observation is that the smaller events, such as the 2, 5, 10, and 15-year events experienced a larger change in peak flow than the higher magnitude events, in terms of a percent increase in peak flow. For all locations in the model, the average percent increase in peak flow is shown in **Table 9.2.1** below.

Table 9.2.1 – Average % Increase in Peak Flows (Base to Forecasted Condition)

Storm Event Frequency:	Dardenne Only:	Tribs Only:	All Streams:
2-year	9.3%	5.0%	6.2%
5-year	7.2%	4.0%	4.8%
10-year	7.5%	3.6%	4.7%
15-year	6.7%	3.3%	4.3%
25-year	5.8%	3.1%	3.9%
50-year	5.7%	3.0%	3.7%
100-year	5.5%	2.8%	3.6%
500-year	4.2%	2.4%	2.9%

Water Surface Elevation Comparison:

The computed water surface elevations for all hypothetical events were tabulated and compared. **Appendix C5** contains the tabulated output data for the eight frequency events for both the base and forecasted conditions on Dardenne Creek. By copying this table from the HEC-RAS output format to Microsoft Excel, a calculation could be made to quantify the change in computed water surface profiles from the base condition to the forecasted condition. On average, each profile showed some small increase over the length of Dardenne Creek and some of its tributaries. A list of the average increase in computed water surface elevation for different portions of the model is shown in **Table 9.2.2** below.

Table 9.2.2 – Change in Water Surface Elevations (Base to Forecasted Condition)

	Average Water Surface Increase (feet)		
Storm Event Frequency:	**Dardenne Only:**	**Tributaries Only:**	**All Streams:**
2-year	0.33	0.13	0.17
5-year	0.26	0.12	0.14
10-year	0.29	0.11	0.15
15-year	0.26	0.11	0.14
25-year	0.22	0.11	0.13
50-year	0.20	0.11	0.13
100-year	0.25	0.14	0.16
500-year	0.37	0.11	0.16

Water Surface Profile Inspection (100-year only):

The HEC-RAS program output can be viewed in various formats, and the profile plot is one of the most useful for comparing calculated water surfaces for two different model runs. In this fashion, the model results from the forecasted condition could be directly compared to the base condition results. In the interest of clarity, one specific storm event, the 100-year event, was chosen for the comparison. A typical section of Dardenne Creek is plotted in **Figure 9.2.1** below. From visual inspection of this profile plot, it can be seen that in some regions, the computed water surface for the forecasted condition is not much different from the base condition. The left side of the graph shows an area with little or no change, just downstream of Highway C and the N&W railroad bridge. On the other hand, a change in the water surface of about 0.5 feet is shown at the right of the graph, between the I-70 and Mexico Road bridges. The profile plot comparing the forecasted and base conditions on Dardenne Creek is displayed in **Appendix C7**. Overall, the visual inspection gives the same basic understanding of the change across the entire length of Dardenne Creek. Typically, the change in water surface elevation from the base condition to the forecasted condition is less than 0.5 feet, and is not even noticeable in some reaches.

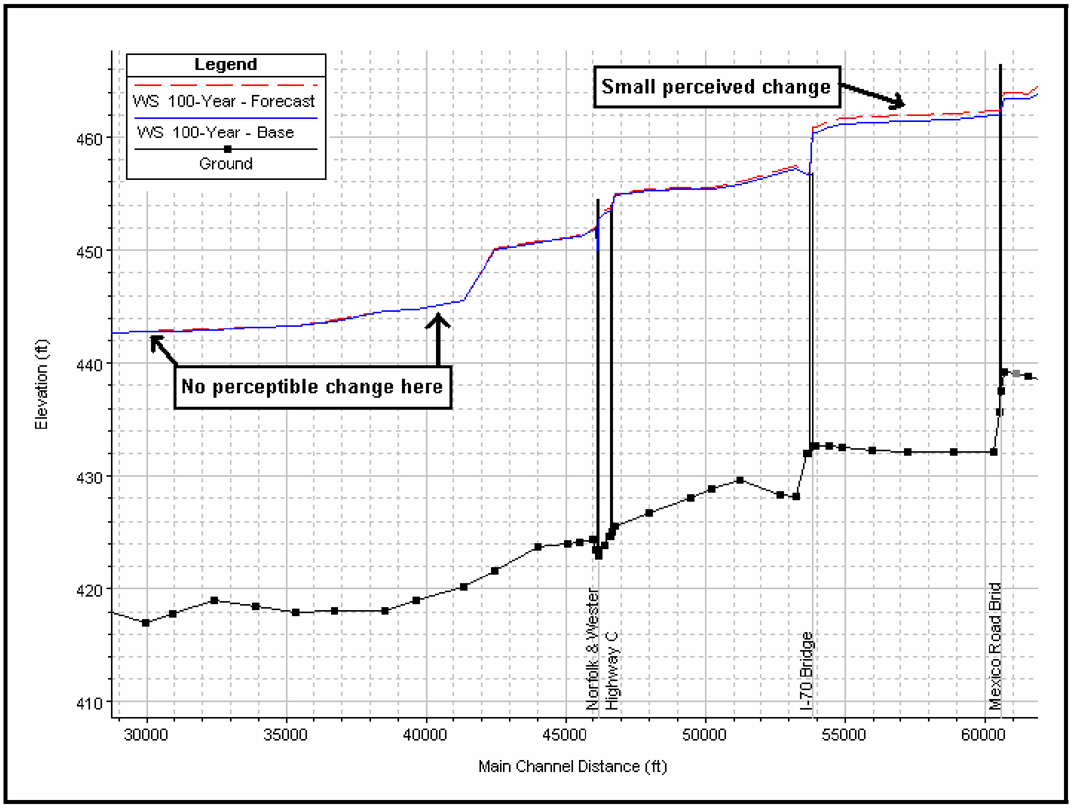

Figure 9.2.1 – Comparison of 100-year Flood Profiles on Dardenne Creek

Flooded Area visual inspection (100-year only):

Another means of comparison to assess the results of the forecasted conditions model involved a visual inspection of the flooded area. In a similar manner described in **Section 9.1** above, the flooded area polygons for both the base condition and the forecasted condition can be produced and viewed in the same GIS window. At first glance, there is very little difference over the course of the watershed. Upon closer inspection, there are instances where the floodplain width increases by about 20 to 40 feet at most. This is not a very large change, and in most cases, the extra floodplain width is still in an undeveloped area near the stream. **Figure 9.2.2** below shows an example of a small increase in floodplain width, on Dardenne Creek near Highway Z. The extra floodplain width can be compared to the width of Highway Z, which runs north and south in the image. **Appendix C9** shows the plot of flooded area for the base condition and the forecasted condition for the 100-year flood. Because of the slight change in flooded area in most locations, the three large pages of plots were not included in the printed copies of the report. Using the DVD or CD copy, however, the "PDF" versions of the plots can easily be viewed or printed.

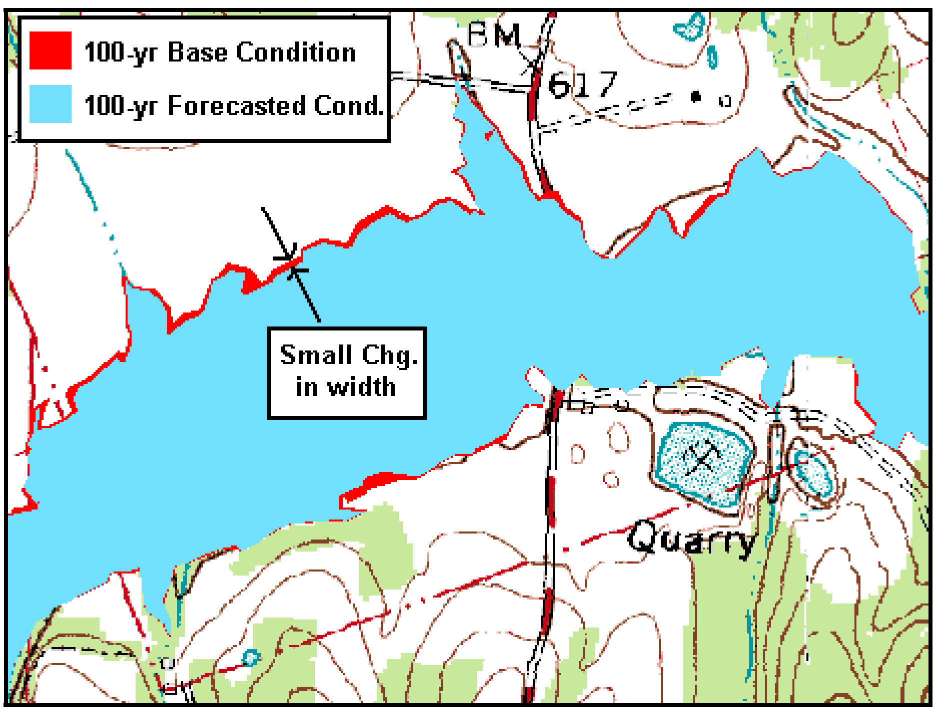

Figure 9.2.2 – Flooded Area Comparison, Dardenne Creek near Highway Z

A slightly more noticeable change from the base condition to the forecasted condition can be observed in the area of East Branch Dardenne Creek. The creek itself has a drainage area of only 1.5 square miles, and it was studied in the HEC-RAS model up to about one mile upstream of Dardenne Creek. Therefore, all of the flooding on this lower portion of the creek can be attributed to the Dardenne Creek backwater. From the flooded area comparison of the forecasted condition to the base condition, it appears that small portions of a residential area may be impacted with a higher likelihood of flooding. The houses are located on Pioneer Drive and Estes Park Drive, just south of Mexico Road. The East Dardenne tributary runs between these two streets, and the area is relatively flat, so a small increase in water surface elevation resulted in a noticeable increase in flooded area. The detail for this area is shown here, in **Figure 9.2.3**.

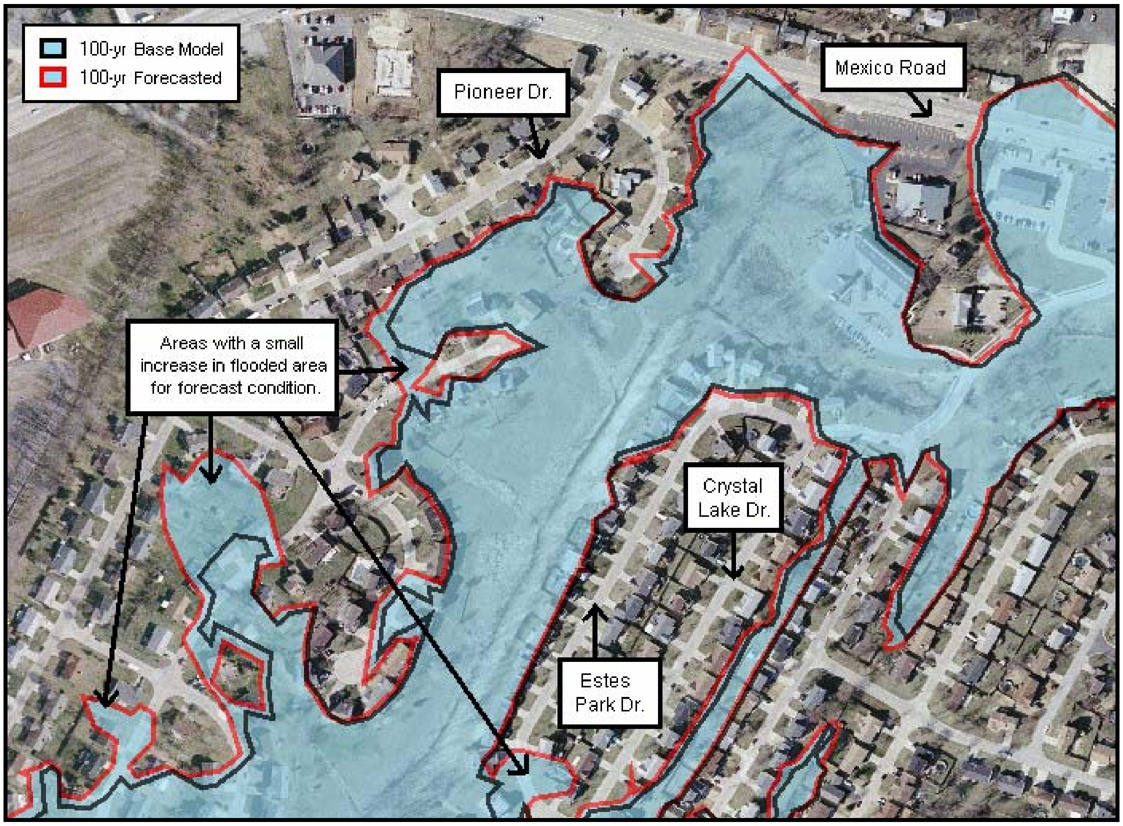

Figure 9.2.3 – Flooded Area Comparison, East Dardenne, South of Mexico Rd.

The properties in question were already considered to be in the 100-year floodplain, according to the original FEMA floodplain maps. While this newer modeling effort shows a higher likelihood of flooding to a greater depth, the structures in the subdivisions may be built up higher than the prevailing ground. Therefore, the first floor elevations should be used to determine if a structure would actually be impacted by the increased flood height. Due to limited accuracy, it is best to use the flooded area maps as an indication of flood-prone areas, using the HEC-RAS model data for a more definitive determination.

Flooded Area calculation (100-year only):

The ArcView GIS program was helpful in developing a quantitative comparison for the change in flooded area between the base condition and the forecasted condition for the Dardenne Creek system. Since GIS data has an exact spatial reference, the area covered by a polygon theme can be easily calculated based on the known extents of the polygon. Using the flooded area polygon features for the base and forecasted conditions, the area calculation was performed for each polygon with the ArcView program. The results show a slight increase in flooded area from the base condition to the forecasted condition, from **33.3** square miles to **33.4** square miles. This represents a change of less than *one third of one percent*. Therefore, as was the case with the flooded area visual inspection, the forecasted watershed conditions for the near future do not result in an extremely noticeable change in the flooded area over the entire project area.

Summary of Forecasted Condition Comparison:

From the various methods of comparison, some conclusions can be made about the impact of the forecasted conditions on the watershed. The main observation was that the forecasted development in the near future of the watershed does not result in a widespread increase in flood heights. For most locations on Dardenne Creek, the increase in the water surface elevation is less than 0.5 feet. In the upper reaches of the watershed, the small rise in elevation has little effect on flooded area, due to the steeply sloping terrain. At the very downstream end of the model, in the Mississippi Floodplain area, the increased water surface also has a negligible effect. This is because the floodplain area is already affected by the 100-year Mississippi River flood, and a small increase in flood height does not have any additional impact. The only noticeable difference in flooded area comes in the middle portion of Dardenne Creek, as mentioned on the previous page.

It is important to note that the Dardenne Creek Watershed Study does not attempt to create an "ultimate" development condition, with the modification to a 100% developed watershed. The Corps of Engineers forecasted condition model is only based on the proposed changes in land use as reported by each city and county in the watershed. Specific development sites were researched and added to the HMS and RAS models, as recommended by the city and county representatives. The forecasted conditions model does not serve either to allow or condemn future development in those instances. The final section of the report covers some of the more probable uses for the Dardenne Creek watershed models.

9.3 Potential Applications

The Dardenne Creek Watershed Study is a tool that can be used to evaluate the watershed response to changing conditions in the region. The main benefit of the model is that it includes Dardenne Creek and all major tributaries in the same hydraulic model, so the changes in multiple areas can be evaluated at the same time. This would be helpful for analyzing the cumulative effects of projects in the area of Dardenne Creek or its tributaries.

The standard procedure for evaluation of projects usually only involves changes to the stream geometry with the hydraulic (HEC-RAS) model. The detailed hydrologic model, created with the HEC-HMS program, offers the user the ability to change hydrologic parameters as well. If a certain region experiences an increase in the amount of impervious area, the effects on the peak flow and the volume of runoff can be evaluated. At the same time, if stormwater requirements were modified, resulting in more stormwater retention, that change could also be modeled with an increase in the time of concentration. If a significantly large retention basin were added to the system, it could even be modeled in HEC-HMS as a reservoir. The functionality of the HEC-HMS and HEC-RAS programs are another added benefit, because they handle water data in the same data format, with HEC-DSS. Therefore, it is not difficult to make multiple model runs and transfer data easily from one program to the other.

Some specific projects that could utilize the Dardenne Creek Watershed model include ecosystem restoration, stream bank stabilization, flood damage reduction, and recreation. As the main project sponsor, Great Rivers Greenway plans to utilize the model to further develop plans for the Dardenne Greenway. This could potentially involve changes to the stream geometry, or possibly to the Manning’s roughness coefficients in the area of the project. The potential impact of the project could be evaluated using HEC-RAS, with the GeoRAS functionality to create flooded area maps. The flooded area maps already created for this project could be used to estimate the current likelihood of flooding in the areas where these recreational projects were proposed. Similarly, any other modifications to the stream geometry for stream bank stabilization or flood damage reduction could be analyzed.

It is important to remember that FEMA’s St. Charles County Flood Insurance Study is still the official document for determining the floodplain and floodway areas. The Corps Dardenne Creek model does not estimate the floodway width or create encroachments on the floodplain. The new Dardenne Creek models are simply tools that can be used by the cities and county as they see fit. Any future project under consideration could be analyzed with the base conditions model to determine the potential effect on the water surface profiles. If desired, the forecasted conditions model could also be applied for another estimate of the potential impacts. However, as stated earlier, the forecasted conditions model will not be the ideal method of analysis to allow or disallow future development. The FEMA Flood Insurance Study is still the official document for floodplain development decisions.

Finally, the U.S. Army Corps of Engineers can be called upon in the future for consultation concerning the HEC-HMS and HEC-RAS models. If a Federal project authority is approved, there is a potential to again utilize Federal funds to enhance the system through ecosystem restoration or flood damage reduction. Contact information for future projects with the Corps of Engineers are listed here:

Project Management:
Deanne Strauser
CEMVS-PM-F
U.S. Army Corps of Engineers
1222 Spruce Street
Saint Louis, MO 63103
(314) 331-8047

Hydrologic and Hydraulic Engineering:
John D. Boeckmann, P.E.
CEMVS-EC-HE
U.S. Army Corps of Engineers
1222 Spruce Street
Saint Louis, MO 63103
(314) 331-8801

List of Appendices

Appendix A – Data Collection

A1. Data Collection Inventory – Data Provided on DVD
A2. Sample Photos from Site Visits
A3. List of Previous HEC-1 and HEC-2 models
A4. Gage Data: Rainfall Data for Calibration Storms
A5. Gage Data: USGS Gage Data for Calibration Storms
A6. Observed High Water Marks – January, 2005

Appendix B – HEC-HMS Hydrologic Model Data

B1. HEC-HMS Basin Schematic
B2. Delineation of Watersheds and Subbasins Plotted from ArcGIS
B3. Basin Loss Rate Data (SCS Method)
B4. Basin Transform Data (Clark Method)
B5. Baseflow Data (Recession Method)
B6. Routing Reach Data (Modified Puls Method)
B7. Reservoir Data (Storage-Outflow-Elevation Curves)
B8. Hydrograph Comparison Plots for Calibration Storms
B9. HEC-HMS Output (Base Condition)
B10. Modifications for Forecasted Condition – Basin Loss Rate
B11. Modifications for Forecasted Condition – Basin Transform Data
B12. HEC-HMS Output (Forecasted Condition)

Appendix C – HEC-RAS Hydraulic Model Data

C1. Plot of HEC-GeoRAS River System and Cross Section Locations
C2. Table of Manning's Roughness Coefficients
C3. Table of Frequency Flows for HEC-RAS Model (Base Condition)
C4. Table of Frequency Flows for HEC-RAS Model (Forecasted Condition)
C5. HEC-RAS Output Tables – Base and Forecasted Condition (all 8 flood events)
C6. HEC-RAS Water Surface Profile Plots – Base Condition for 10, 50, 100 & 500-yr floods
C7. HEC-RAS Water Surface Profile Plot – 100-year Base vs. Forecasted Condition
C8. GIS Plots – 100-Year Floodplain (New Model vs. FIS floodplain limits, all areas)
C9. GIS Plots – 100-Year Floodplain (Forecasted Condition vs. Base Condition, selected areas)
[Note: C8 & C9 are in digital format, but not included in printed copies unless requested]

Appendix D – Supporting Documentation

D1. Original Scope of Work for Dardenne Creek Study
D2. Computer Software References
D3. Other Reference Materials
D4. Abbreviations and Definition of Terms